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STEALTH

OPERATIONS DECLASSIFIED

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That Night in '94...

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Reducing RCS

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Striking Daesh

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Introduction

I STILL RECALL the ITN TV news broadcast on November 10, 1988. I'd just got home from school and sat in the living room captivated as an official at a Pentagon press conference held up a grainy black and white image of a diamond-shaped aircraft.

He explained that the US Air Force had been test flying this jet in the deserts of California.

The information was vague. Specific details about the aircraft – its performance, how many there were, who was flying them and where – were left out. The photograph didn't give too much away either, but I was hooked.

Since then I've followed the development of stealth aircraft with great interest. Although I've never been given access to the so called 'black world' where all these classified projects begin and where they undergo testing, I've gathered plenty of information.

And I've been fortunate enough to have spoken to individuals involved with these highly clandestine programmes who've revealed just how revolutionary this technology was – and is.

"It's not making an aircraft invisible, we've just learnt how to direct the radar returns to go somewhere else," was a familiar phrase I heard at defence conferences.

How they'd learnt how to do it, and with what, were the real secrets, and no-one was telling.

Every now and then I'd come across a report in a defence journal where a former senior air force officer would state that 'stealth technology' is no longer applicable within today's predicted air warfare scenarios. I very much doubt that.

The 'stealth genie' was let out the bottle back in the 1970s. Lockheed pioneered the technology, followed quickly by Northrop Grumman and a select number of other US companies, many of whose locations and details have never been revealed to the public.

It was inevitable that the technology would filter across to Europe and beyond, either through collaborative programmes or through technology being 'acquired' surreptitiously via spies, corrupt officials or hackers from a company website.

This *AirForces Monthly* special brings together highlights of past, present and future stealth programmes from the big players in the industry. Information continues to be released on former US black programmes and, on occasions, there are glimpses of current secret American projects as well.

It must be hard for those involved in the black world not to even hint at the revolutionary technology they're working on.

The Russian and Chinese have new stealthy fighters that, at least on paper, look to be an equal match for those of the US.

Technologies developed in the pioneering days have been applied to a host of unmanned aerial vehicles, many of which remain just as secret as their piloted forebears.

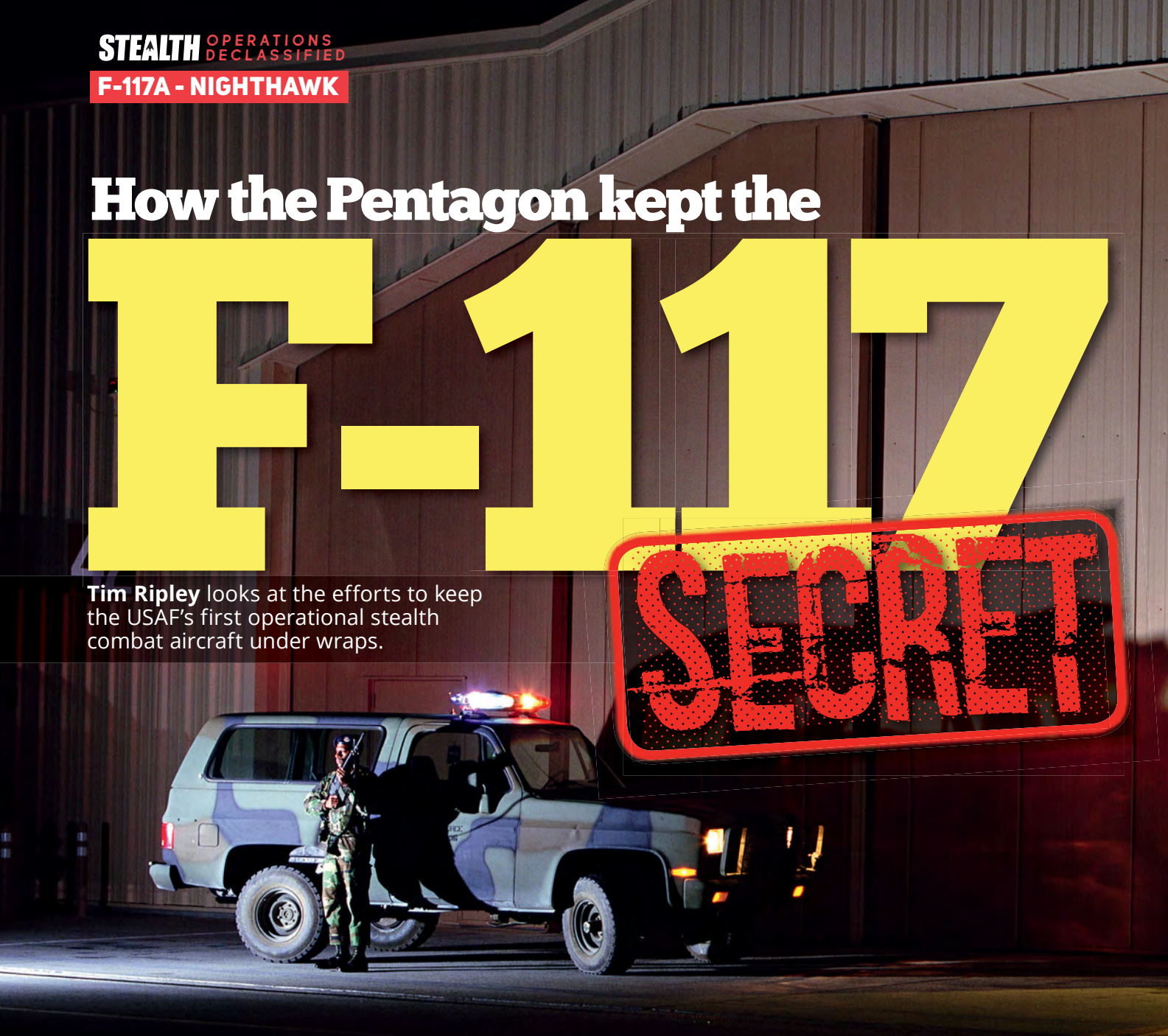
Stealth has gone far beyond that awkward black wobbly jet that looked more at home on an ironing board than in the skies of California or over Baghdad.

But, some 40 years after stealth became a media catchword for anything classified as 'top secret' in the defence community, I bet somewhere at a remote test site an aeronautical engineer is turning to his design team and asking: "Looks great, just what the air force wants, but is it stealthy?" **Glenn Sands**

Right: An extraordinary shape, revolutionary radar-defeating features and a top secret, yet glamorous development combined with a star appearance in Desert Storm to make the F-117 Knighthawk the best-known warplane in the world during the 1990s. *Richard Cooper*

How the Pentagon kept the F-117 SECRET

Tim Ripley looks at the efforts to keep the USAF's first operational stealth combat aircraft under wraps.



ON NOVEMBER 10, 1988 the Pentagon unveiled a fuzzy picture of America's previously top-secret stealth fighter aircraft. For the first time, the US Government revealed the real designation of the aircraft – F-117 – and they detailed how many had been built, where they were based and some information on known crashes. The imagte made newspaper front pages across the world. The project's 'black', or secret, nature caught the public's imagination.

Over the next two years more information was gradually released about the Lockheed F-117, which culminated in the appearance of the aircraft at airshows around the world in the aftermath of the 1991 Gulf War. Enthusiasts could walk up to within a couple of metres of the aircraft and marvel at its bizarre shape. Armed USAF security police posted around the black jets, however, reminded visitors that the F-117 was not yet completely in the open.

The story of how the Pentagon kept the F-117 secret for more than a decade gives an interesting insight into the workings of US 'black' procurement programmes.

Above: ***Hidden away in the remote Cactus Flats, Tonopah Test Range was an excellent location for a classified programme. Security was without precedent for an operational unit of this size, with a layered approach keeping out all but fully authorised personnel.*** *USAF via Warren Thompson*

Below: ***Tonopah Test Range was little more than an airstrip in the desert for supporting missile trials before the 4450th arrived. A massive building programme started in 1982-83 to support the F-117s, including a larger runway, taxiway and a Wing headquarters.*** *USAF via Warren Thompson*

Science Project

The science of stealth, or low observable technology, is as old a radar itself. As soon as the Royal Air Force deployed radar to defend the British Isles against Hitler's Luftwaffe in the first years of World War Two scientists were trying to work out ways to defeat the early warning technology.

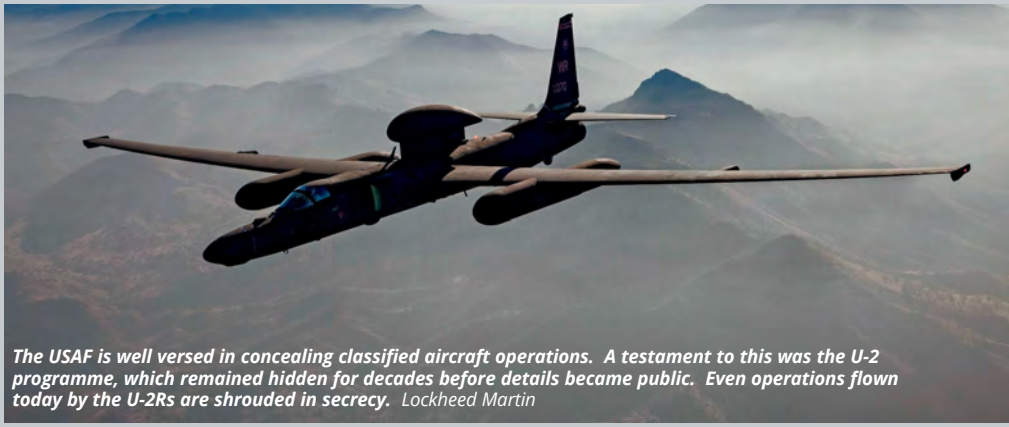
Radar works by bouncing a radio signal off an aircraft and then studying its return to pinpoint the location, size and shape of the enemy airframe. By modifying the design of the wings and fuselage to reduce or confuse a tracking signal, the target aircraft can be made to disappear from the radar operator's screens or at least reducing its size to such an extent that the operator cannot identify it as an enemy aircraft. This is at the heart of claims that stealth aircraft look like birds on the screens.

During World War Two the Germans experimented with coating aircraft in charcoal to act as an early type of Radar Absorbent Material (RAM) in a bid to stop the radar signal bouncing off their aircraft. The radar returns of metal and

Above: ***At Tonopah each aircraft was housed in a separate barn, where all the pre-flight checks were undertaken to hide the aircraft from passing satellites. Prior to the F-117s going public, the barn could not be opened until one hour after sunset, and had to be shut one hour before sunrise.*** *USAF via Warren Thompson*

Above: ***A satellite view of Tonopah at the height of F-117 operations. The larger runway, taxiway, ramp space and operating facilities can be seen along with the individual barns for the F-117s. Housing for base personnel was 7 miles from the airfield site.*** *USAF via Warren Thompson*

Right: ***The badge of the 4450th Tactical Group.***



The USAF is well versed in concealing classified aircraft operations. A testament to this was the U-2 programme, which remained hidden for decades before details became public. Even operations flown today by the U-2Rs are shrouded in secrecy. *Lockheed Martin*

wood constructed aircraft were already being compared and several scientists were considering how to make the internal structures of aircraft less likely to generate big and obvious radar returns.

Both the Lockheed U-2 Dragon Lady and SR-71 Blackbird high-flying spy planes incorporated design features to reduce their radar cross sections, but the US had not yet designed and built an aircraft that was intended to be stealthy from scratch. This changed in the 1970s in response to the heavy losses to Soviet-made radar guided surface-to-air missiles in Vietnam and 1973 Arab-Israeli war. In the mid-1970s, the Pentagon ordered construction of a small tactical combat aircraft that would be able to penetrate Soviet-designed air defences and conduct pinpoint air strikes. It was never intended to be an air supremacy fighter, but the US military deliberately let the media continue to call the aircraft a fighter to add to the confusion about the role and capabilities of the new aircraft.

The US-aviation technical press published several accounts about the launch of the project – which later was revealed to be called Have Blue and was in effect a scaled down version of the F-117 – in the late 1970s but they attracted little attention in the popular media.

This changed during the 1980 US Presidential election campaign when President Jimmy Carter's Democratic administration was accused by its Republican opponents of being 'soft' on the Soviets. In a bid to counter these claims, Carter's team revealed details of the radar-evading fighter project. The strategy backfired and the Republicans accused Carter of leaking America's secrets.

When Ronald Reagan replaced Carter in 1981, he ordered a total security clampdown on the project. It became a fully fledged 'black' project. The Pentagon and USAF made no references to the aircraft in its published budget requests to Congress. A secret, or closed, Congress committee had to approve all funding on the project. The unit that operated the aircraft was classified as top secret, as was its base, role and any technical details of the aircraft, including its designation. No photographs of the aircraft were released. The contractors who built it – Lockheed – where not allowed to refer to the fact they had a US$6.56bn contract from the Pentagon. All workers – even down to the cleaners on the production line at Palmdale, California – on the programme had to have top-secret security clearances. It was as if the aircraft did not exist, even to the extent that a senior Pentagon official said reports about it were "wishful thinking".

The security measures paid dividends – the F-117 remained a secret for five years before the Pentagon finally released details. *USAF via Warren Thompson*

The X-Files

America is often called the land of the conspiracy theory and despite the unprecedented security clampdown throughout the 1980s there were persistent media reports about the existence of the aircraft. A plastic construction kit appeared and a number of artists' impressions of its design were published. There were claims it was designated the F-19. Several reports in the mainstream media gave details of when the aircraft had entered production, how many were to be built and its possible role.

Most of the reporting of the design of the stealth fighter drew on the original reports

Left: ***Prior to the unveiling of the F-117, the aviation media speculated that the classified stealth fighter was designated the F-19 and used a futuristic blended-body design.*** *Loral Industries*
Below left: ***During the day F-117 pilots used A-7Ds as companion trainers, carrying an LV tail code for 'Las Vegas'. These were replaced in 1989 by T-38As.*** *Tom Kaminski*
Below: ***Two A-7Ks were acquired by the 4450th and used by pilots to evaluate sortie profiles they would later conduct in the F-117. The group was the only active-duty unit to fly the A-7K within the USAF.*** *Brian C Roger (Lt Col USAF Ret'd)*
Insert: ***The Q-Unit of the 4452nd Test Squadron, which began as Det One of the 4450th, was nicknamed 'Goat Suckers'. In the 1980s it evaluated a growing squadron of top-secret stealth fighters at the Tonopah Test Site when the Group HQ was still at Nellis AFB. The unit flew A-7s as a cover story for the F-117.*** *Glenn Sands Collection*

from the 1970s and combined it with generic scientific information about how RAM technology worked. Some elements of these reports were accurate, but when they were all combined it was clear that the security clampdown worked in terms of preventing the public – or hence potential adversary – gaining a true understanding of the design of the aircraft. By keeping the shape of the aircraft secret for as long as possible, the USAF hoped to prevent adversaries redesigning their air defences in response.

Once production F-117s started to be delivered from the Palmdale factory to the USAF's operational base at Tonopah, Nevada, the Pentagon faced the problem of dealing with sightings of the aircraft or reacting if any crashed. The way the USAF put in place real-life security measures appears to have been the inspiration of several plot lines in the science fiction television series, The X-Files, that appeared in the early 1990s.

To limit sighting, the F-117 was strictly ordered to fly only at night. This applied even to high restricted air space over the USAF Nellis range complex in Nevada in case civilian aircraft strayed close by.

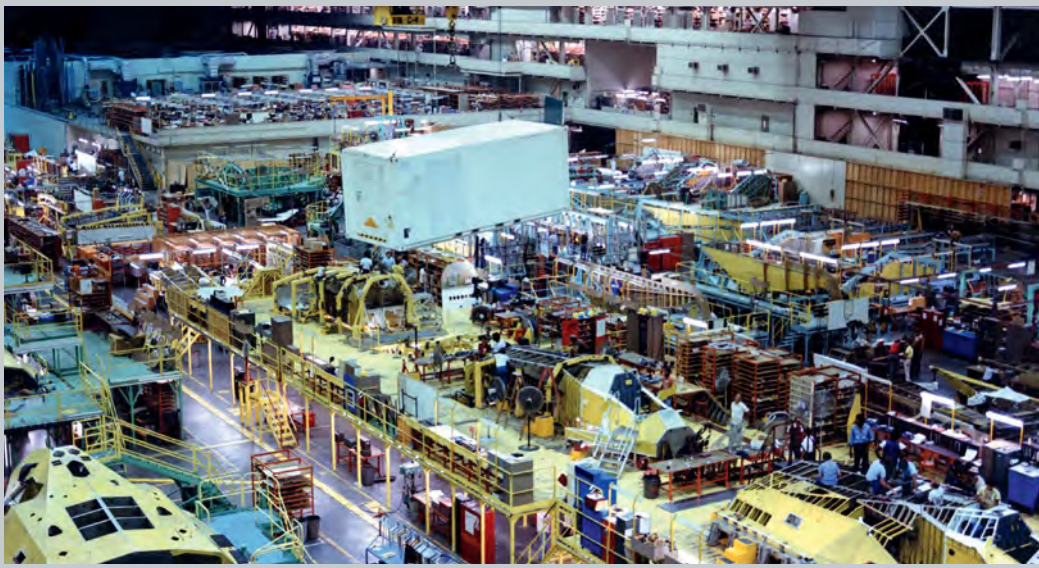
An F-117 crash in California in July 1986 tested the ability of the USAF to keep its secrets under wraps. A five-mile-wide and 8,500ft high air exclusion zone was placed around the crash site to keep civilian aircraft away and non-military firefighters were banned from attending the crash. The security cordon remained in place for several weeks as USAF recovery teams removed all the wreckage.

In an added twist, after the teams completed their work the USAF reportedly scattered fragments of an F-101 Voodoo jet around the site to confuse the journalists and foreign agents who were expected to descend on the site after the cordon was lifted.

The following year another F-117 crashed on the Nellis range and again a security clampdown was ordered, including banning civilian firefighters from attending. Within weeks, a USAF A-7D Corsair II crashed into a hotel in Indianapolis, Indiana, killing ten civilians. This prompted media speculation about the USAF's stealth unit because the pilot of the A-7D was identified as belonging to the same unit – the 4450th Tactical Training Group - as the pilot who was killed in the Nellis range crash.

After these crashes the USAF refused to divulge the type of aircraft involved, the causes of the accidents or their home base. Pentagon press officers stonewalled any media inquiries with evasive replies.

By 1988 the Pentagon had concluded that there was now little to be gained from keeping the F-117 'in the black' any longer. The night-flying restriction was severely hampering pilots' training. The USAF was also soon to begin a pitch to Congress for multi-billion-dollar funding to launch production of the stealth B-2 bomber and Advanced Tactical Fighter, which ultimately became the F-22, so some publicity about the F-117 could be beneficial. These new aircraft featured more advanced 'smooth' stealth features so the F-117s faceted design was expected ➤



Above: ***Lockheed's production line illustrating at least six F-117s under construction. Despite the tight security it is widely believed Soviet intelligence had penetrated the site.*** *Lockheed Martin via Warren Thompson*

Right: As the security blanket on the F-117 was slowly removed, the aircraft began daylight sorties, greatly easing pilot fatigue that had afflicted the unit through its first five years of operations. *USAF*
Below: The canopy of F-117A 82-0806 'HO' following its shoot-down on March 27, 1999, during the fourth night of Operation Allied Force over Serbia. The pilot ejected safely. *Serbian Air Force*

to be superseded in the near future.

Lockheed employees were also poised to sue the Pentagon claiming they had been poisoned by toxic material used in the manufacture of the F-117. So rather than be forced to disclose the F-117 in a court case, the Pentagon decided on a pro-active approach. Hence the November 1988 announcement confirming the existence of the F-117.

Did the Secrecy Work?

In January 1991, the USAF dramatically announced that the F-117s had opened Operation Desert Storm by penetrating Iraqi air space to strike at targets in the heart of Baghdad. The famous 'black jets' appeared to achieve total surprise and dropped their bombs before being detected by the Iraq's Soviet-made air defence radars. The secret of the F-117s radar evading technology had not been compromised by Saddam Hussein's sophisticated radar network.

Even though the media had been taken to see the F-117 at their airbase in Saudi Arabia and the aircraft were subsequently put on display at air shows in the US and Europe, the USAF still kept a tight hold on the information about the aircraft's design. In particular, any details of the properties of the F-117's RAM and the internal design of the aircraft were kept under wraps. Knowledge of the the positioning of load-bearing struts, fuel tanks and other major internal structures would be of great help to anyone trying to design radars to detect an F-117. Also measures to protect the thermal or heat signature of the aircraft's engines have remained secret. All these technical features remain highly classified years after the F-117 was retired from frontline service.

While the Iraqis remained in the dark about the F-117, there remains a long-running suspicion that the Soviet intelligence had penetrated Lockheed's Palmdale plant, where the aircraft and its prototypes were designed and manufactured. Blueprints and photographs of the F-117 reportedly went missing from Palmdale during the 1980s, prompting a congressional investigation. One worker allegedly smuggled out blueprints from the factory to impress his girlfriend. In such an environment, did the infamous KGB manage to steal the secrets of the F-117? At the same time,

Above: Stealth secrets gathered by the KGB during the 1980s are believed to have led to the development of a whole new range of SAMs including the highly capable, long-range S-400 Triumph. *Andrey Zinchuk via Alexander Mladenov*

a high-profile Soviet spy ring infiltrated the US Navy's most advanced submarine tracking operation prompting suspicions that some F-117 secrets reached Moscow.

At this time, the Soviet Union was in process of imploding and by the end of the 1980s the Communist superpower was in crisis. Its arms industry was in turmoil as the money from Moscow to build new weapons dried up. Even if the KGB had been able to gain access to F-117 secrets, the new Russia's military and arms industry was in no position to exploit them. It was not until 1999 that the Russians were able to fund work on the S-400 surface-to-air missile (SAM) that might have incorporated data from the F-117.

In March 1999 the USAF lost an F-117 during the NATO air campaign over Serbia, which led to more speculation that its secrets had been compromised. The Serb SAM commander who shot it down subsequently disputed these claims, saying he had modified his S-125 Neva (SA-3 Goa) SAM system to operate on a wider frequency range. This enabled his radar operators to spot when the F-117 opened its bomb bay doors as it approached its target, which temporarily increased its radar cross section. They were then able to fire off a missile and a proximity fuse detonated its warhead, badly damaging the F-117. Fortunately, the F-117 pilot was able to eject safely and was successfully rescued by US Special Forces helicopters later that night. The Serbs used some basic science and got lucky. A senior USAF officer familiar with the F-117 commented at the time: "It was bound to happen one day – the F-117 does not have a Star Trek force field to protect it against enemy missiles or gun."

The security drive to protect the secrets of the F-117 must be considered a major part of its success. From the mid-1980s for ten to 15 years, the F-117 was ahead of any known threat. However, it was only a matter of time before America's enemies worked out how to defeat its technology.

C1000 Typhoon - Cockpit Edition

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Reducing Radar Reflections

Tim Ripley explains the scientific breakthroughs that helped produce the minimal radar cross sections of today's stealth aircraft.

THE LATE 1930s' development of radio direction and ranging – radar – changed the face of aerial warfare. Radar signals were transmitted into the sky, where aircraft could reflect them. Receivers on the ground picked up these reflections, or returns, detecting multiple reflections over a period of time, which could be compared with each other to help work out the target's direction of travel and speed.

As radars became more sophisticated during World War Two, scientists gained a deeper understanding of the factors that influenced the size of the reflection from the target, which became known as radar cross section (RCS). They came to appreciate that the larger its RCS, the easier it was for radar to detect and track an aircraft.

Several factors were recognised as critical in determining an aircraft's RCS, including the material it was made from, its absolute size and relative size to the wavelength of the radar illuminating it. Then it became clear that RCS was also affected by the angle at which the radar signal hit a particular portion of a target and the angle at which the reflected signal left the target. This, in turn, was dependent upon the position of the transmitted and returned radar signal in relation to the orientation of the target.

The 1980s brought significant advances in stealth technology enabling the classified techniques to be applied to highly-manoeuvrable fighter designs such as the F-22A Raptor. *USAF/Justin Connaher*

Apart from the flat facets making up its exterior, the F-117 exhibited many other features for a low radar cross-section notably in the front hemisphere. The straight line running from the nose to wingtip (swept at 67.5°) and similar sharp-angled sweep-back on the fins is a major dissipater of radar energy away from its source. The glazed panels were coated with gold to conduct radar waves into the airframe. Necessary holes in the overall shape for the engine intakes and sensors were covered with a grille. *Richard Cooper*

It is usually the case that the larger an object the stronger its radar reflection and thus the size of its RCS, but specific RCS is dependent on the wavelength of the radar signal and target reflectivity. Metallic materials are strongly radar reflective and tend to produce a larger RCS, whereas the wood and cloth used in aircraft dating from the 1940s and earlier are less reflective. Plastic and fibreglass can be almost transparent to radar, making them suitable for radomes. Even a very thin layer of metal can make an object strongly radar reflective, as is the case with the chaff used to decoy surveillance radars or radar-guided missiles.

From the side, an aircraft may generate a larger RCS than when illuminated from the front, making the orientation between radar transmitter and target extremely important. Indentations on wing and fuselage surfaces can also act as reflectors, increasing RCS. Open bomb bays and doors, engine intakes, pylons and joints between aircraft structural sections all increase RCS. The position and shape of internal structures, including engines, wing spars, ejection seats and fuel tanks can also influence radar reflectivity.

Supercomputers

The calculation of RCS is dependent upon complex mathematical formulae. As the power of computers advanced in the 1950s and 1960s they were increasingly used to process and analyse radar returns, with a dramatic increase in the performance of radar systems. But at the same time it became apparent to US scientists that the formulae could also be used to reduce reflectivity.

During the 1960s, the first radar absorbent materials (RAM) were used on the high-flying Lockheed A-12 spy plane. The RAM concept has the material 'soaking up' radar signals, degrading the strength of the return to the illuminating radar.

Above: The Lockheed A-12 was the first generation of stealth aircraft to combine the new technology of radar absorbent materials (RAM) with a blended wing/fuselage design. *Lockheed Martin*

More than half a century later, the exact composition of the various RAMs available is highly classified, but some forms are understood to comprise microscopic metallic balls suspended in a thick paint or resin.

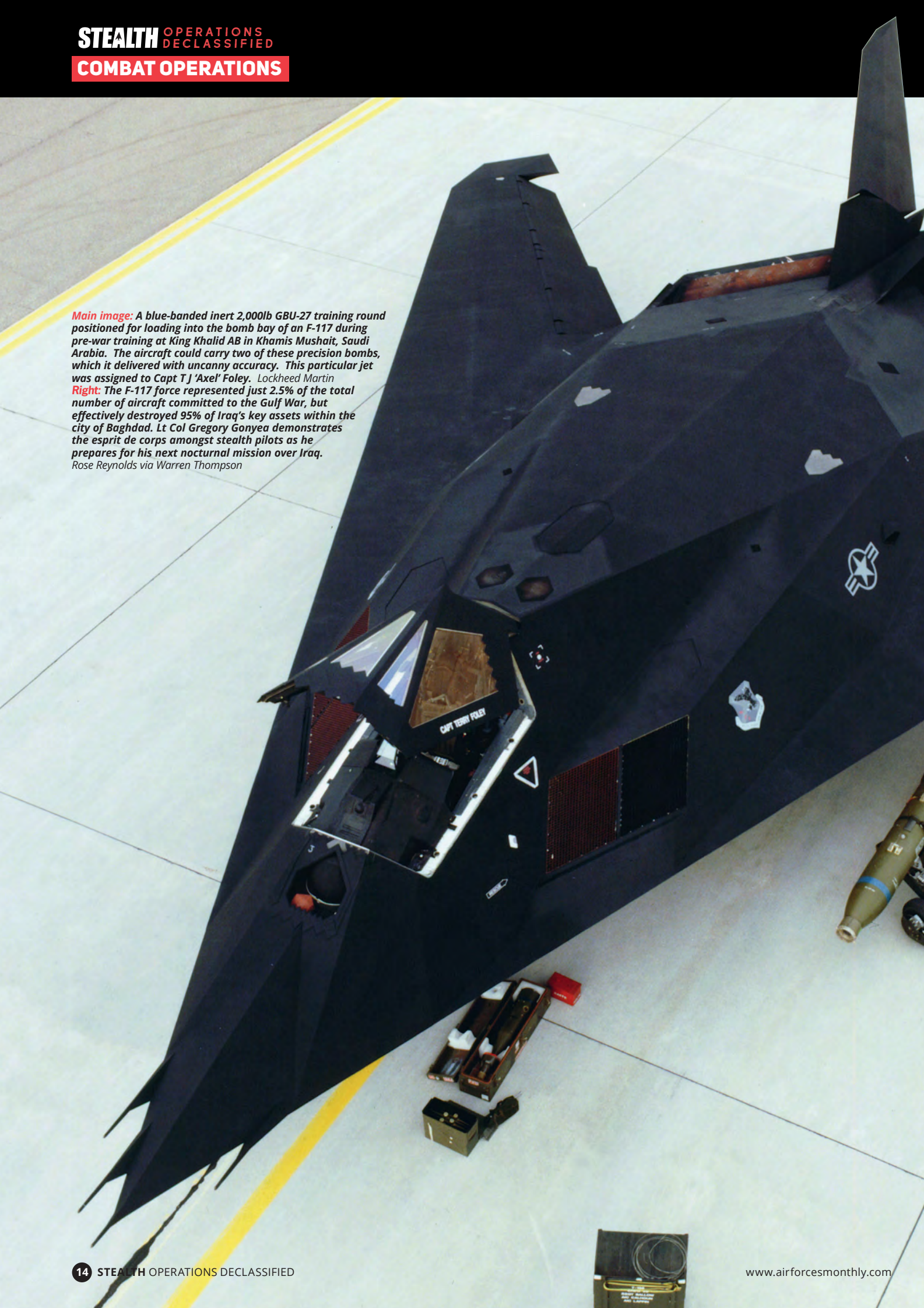
In the 1970s, the US moved to take stealth a step further and several experimental aircraft were developed to prove the faceting concept that eventually emerged on the Lockheed F-117 Nighthawk. The idea was to make the aircraft so angular that any signal hitting it would not be reflected directly back towards the illuminating radar, rendering the F-117 near invisible. The designers benefited from the examination of several Soviet air defence radars captured by Israeli forces from Arab armies in the 1967 and 1973 Middle East wars, increasing their understanding of the wavelengths they used.

In the 1980s the US made major advances in stealth with the design of the B-2 Spirit bomber and F-22 Raptor fighter, which both featured curved shapes. These aircraft, as well as the more recent F-35 Lightning II, which has a similar shape to the F-22, benefited from the use of supercomputers capable of calculating far more permutations of radar reflection and from multiple directions.

Features that have been used to reduce RCS include the very thin, sharply swept wings of the F-117. In addition, canted vertical tail surfaces or, in the case of the B-2, none at all, present as few radar-reflecting vertical structures as possible.

The B-2, like the F-117 before it, also has its engine intakes set back on top of its wings to reduce their RCS, while sinuous intake trunking and special blanks help keep radar energy away from highly reflective engine faces. The F-117, F-22, F-35 and B-2 all make extensive use of RAM, that used on the F-35 being far more robust than the materials used on the B-2, which requires climate-controlled hangars and protection from rain and sunlight.

The F-35 also benefits from advanced manufacturing that makes its surfaces and the joints between skin sections as smooth as possible, helping minimise RCS.



Main image: ***A blue-banded inert 2,000lb GBU-27 training round positioned for loading into the bomb bay of an F-117 during pre-war training at King Khalid AB in Khamis Mushait, Saudi Arabia. The aircraft could carry two of these precision bombs, which it delivered with uncanny accuracy. This particular jet was assigned to Capt T J 'Axel' Foley.*** *Lockheed Martin*
Right: ***The F-117 force represented just 2.5% of the total number of aircraft committed to the Gulf War, but effectively destroyed 95% of Iraq's key assets within the city of Baghdad. Lt Col Gregory Gonyea demonstrates the esprit de corps amongst stealth pilots as he prepares for his next nocturnal mission over Iraq.*** *Rose Reynolds via Warren Thompson*

Stealth Fighters
Combat Operations

Tom Kaminski provides an overview of combat operations for the world's first stealth fighter, the F-117 Nighthawk.

BETWEEN JUNE 1981 and July 1990 Lockheed's Skunk Works division in Palmdale, California, produced five developmental and 59 operational F-117As for the US Air Force, at a cost of $6.56bn. Ten Nighthawks were assigned to the 4450th Tactical Group when it achieved limited initial operating capability at the Tonopah Test Range in Nevada, on November 1, 1983.

In October 1983, a number of F-117As were flown from the Tonopah base to Myrtle Beach AFB, South Carolina, in preparation for an attack on Palestine Liberation Organization (PLO) facilities and PLO sympathisers/terrorists in Southern Lebanon. The attack targeted positively identified locations of the terrorist groups that were known to be responsible for the truck bomb that destroyed the US Marine Corps barracks and resulted in the deaths of 241 US military personnel in Beirut. The mission was, however, scrubbed just 45 minutes before the Nighthawk's scheduled launch time.

The Nighthawk's existence was finally confirmed on November 10, 1988 by the Pentagon and the stealth fighter was displayed publicly for the first time at Nellis AFB, Nevada, on April 21, 1990.

Just one year after the Nighthawk's existence was revealed, the 37th Tactical Fighter Wing (TFW) launched eight F-117As from Tonopah, for a mission in support of the US invasion of Panama as part of Operation Just Cause.

Two of the aircraft supported the parachute drop of US Army Rangers against a Panama Defense Forces facility at Río Hato during the US invasion of the Central American nation on December 20, 1999. Although just two GBU-27 2,000lb laser-guided bombs were dropped near troop barracks adjacent to an airfield, the mission marked the combat debut for the Nighthawk.

Reports at the time indicated that the bombs were intended to "disorient, stun and confuse" the Panamanian troops and the aircraft were used because of their bombing accuracy rather than their radar-evading capabilities. Four additional F-117As had been assigned to support forces that were tasked to capture President Manuel Noriega. The aircraft had been charged to attack his two known residences but were recalled without striking the targets when it was determined that Noriega was not there. Following the mission all six F-117As recovered at England AFB, Louisiana, and returned to Tonopah the following day. Two additional F-117As that had been launched as spares did not proceed to Panama and returned to Tonopah.

Above: ***The new HAS complex at King Khalid AB, had been built to accommodate Saudi F-15s. The 37th Wing could house at least two F-117s per shelter.*** *Rose Reynolds via Warren Thompson*

Desert Shield/Desert Storm

Under orders from President Saddam Hussein, Iraqi military forces crossed the border and invaded the Emirate of Kuwait, on August 2, 1990. Five days later President George H W Bush ordered US forces to the region as part of Operation Desert Shield. On August 19, 21 F-117As operated by the 37th Tactical Fighter Wing's 415th Tactical Fighter Squadron (TFS) departed Tonopah en route to Langley AFB, Virginia. While three of the original aircraft, which were tasked as spares, returned to Tonopah on August 21, the remaining 18 completed the trip to King Khalid Air Base in Khamis Mashayt, Saudi Arabia.

A second group of Nighthawks operated by the wing's 416th TFS arrived at the Saudi base on December 4 and on December 20; the two squadrons were assigned to the 37th Tactical Fighter Wing (Provisional). On November 29, the United Nations Security Council approved a resolution that authorised the use of force to remove the Iraqi forces from Kuwait. As a result, on the night of January 17, 1991, coalition forces were launched against Iraq. The first wave of the attack included ten F-117As from the 415th TFS that targeted key air defence and command, control and communication (C3) facilities in an around Baghdad that included bunkers located within the Abu Ghraib Presidential Palace. During the first night of Desert Storm, 29 F-117As delivered 49 laser-guided bombs that struck 26 high-value targets. An additional group of F-117As and pilots from the 417th Tactical Fighter Training Squadron also arrived in Khamis Mashayt on January 26, to bring the number of deployed F-117As to 42.

During subsequent missions the Nighthawks repeatedly struck key political and military targets to weaken Iraqi command and control and its ability to conduct co-ordinated combat operations in preparation for the planned ground campaign. Early in the conflict four Nighthawks attacked an Iraqi nuclear research facility, destroying its three reactor cores.

In another strike, the 37th TFW (P) destroyed an entire network of surface-to-air missile sites in central Iraq in just one hour. Immediately prior to the start of the coalition ground campaign, which began on February 24, 1991, the Nighthawks destroyed a complex of pumping stations and a distribution network that fed oil into anti-personnel fire trenches in southern Kuwait.

Through the brief conflict the F-117As were the only aircraft that struck targets in 'downtown' Baghdad. The Nighthawks were repeatedly tasked to attack key political and high-value targets – military and government targets including the Iraqi Ministry of Defence, Air Force

Left: The average F-117 mission took from five to eight hours depending on the location of the targets in Iraq. Missions along the Turkish border lasted at least eight hours and required multiple visits to an orbiting tanker. *Rose Reynolds via Warren Thompson*

Below: Ordnance personnel watch an F-117 taxi by en route to its take-off position. Both jets were probably slated for the first mission of the night, which usually launched at dusk. *Rose Reynolds via Warren Thompson*

INDIVIDUAL F-117 COMBAT MISSIONS

Aircraft No.	*Just Cause*	*Desert Storm*	*Allied Force*	*Iraqi Freedom*	Total Combat Missions	Notes
79-10780						Full-scale development aircraft – no combat missions
79-10781						Full-scale development aircraft – no combat missions
79-10782						Full-scale development aircraft – no combat missions
79-10783						Full-scale development aircraft – no combat missions
79-10784						Full-scale development aircraft – no combat missions
79-10785						Crashed Apr 20, 1982 – no combat missions
80-0786		24	34		58	
80-0787						No combat missions
80-0788			44		44	
80-0789		31		9	40	
80-0790				30	30	
80-0791						No combat missions
80-0792						Crashed Jul 11, 1986 – no combat missions
81-10793		33	37		70	
81-10794		35	29		64	
81-10795			31		31	
81-10796		29			29	
81-10797		8			8	
81-10798		34			34	
82-0799		21	22		43	
82-0800			38		38	
82-0801		38			38	
82-0802		19			19	
82-0803	1	33	44		78	
82-0804						No combat missions
82-0805			50		50	
82-0806		39	5		44	Shot down over Yugoslavia – Mar 27, 1999
83-0807		14	43		57	
83-0808		37			37	
83-0809			17		17	
83-0810		26	18		44	
84-0811		33			33	
84-0812		42			42	
85-0813	1	35			36	
85-0814		34			34	
85-0815						Crashed Oct 14, 1987 – no combat missions
85-0816	1	39		8	48	
85-0817	1	18	40		59	
85-0818	1	38	12	9	60	
85-0819		30	20	5	55	
85-0820			37		37	
86-0821		32	19		51	
86-0822						Crashed May 10, 1995 – no combat missions
86-0823						No combat missions
84-0824			27	6	33	
84-0825		33		5	38	
84-0826		29	31		60	
84-0827						No combat missions
84-0828			33		33	
85-0829		23			23	
85-0830		31			31	
85-0831						Test no combat missions
85-0832		30	17		47	
85-0833		30	45		75	
85-0834	1	34		6	41	
85-0835		26			26	
85-0836		39			39	
86-0837		31			31	
86-0838		36			36	
86-0839		39			39	
86-0840		32			32	
88-0841		18			18	
88-0842		33	23	9	65	
88-0843		33	27		60	
Total	6	1,219	743	87	2,055	

***Above:** An F-117 armed and ready for its next mission, loaded with a pair of GBU bombs. For most missions just one bomb at a time was dropped allowing the jets to destroy two separate targets, which could be up to 20-minutes' flying time apart.* *Ken Huff via Warren Thompson*

Headquarters, the General Directorate of Intelligence (GID) Headquarters, presidential palaces, air defence radar and missile sites, *Scud* missile sites, transportation and communications facilities, ammunition depots, highway bridges, airfields, other government facilities and suspected chemical and biological warfare facilities.

On February 28, just four days after the ground campaign began and two days after Iraqi forces left Kuwait, the air campaign came to end. Iraq subsequently formally accepted the terms of a ceasefire on March 3, 1991.

Flying only at night, F-117As flew 1,219 missions totalling around 7,000 combat hours during Operation Desert Storm. Around 33% of those missions were flown over or around Baghdad, which was reportedly ringed with 3,000 ➔

Above: ***An F-117 is towed back to the HAS after returning from its last mission of the night. Crews of the third and final wave of 'black jets' found it difficult to make it back out of Iraqi airspace before sunrise.*** *Rose Reynolds via Warren Thompson*

pieces of anti-aircraft artillery (AAA) and more than 60 surface-to-air missile (SAM) sites. Throughout the 43-day air campaign, the 37th TFW(P) generated an average of 2.5 waves of strikes nightly.

The aircraft delivered more than 2,000 bombs, which primarily comprised the laser-guided 2,000lb GBU-27 Paveway III and GBU-10 Paveway II. The deployed pilots flew an average of 21 flights during the conflict. On the first night of the war, 36 F-117As, comprising just 2.5% of the coalition tactical strike aircraft were responsible for attacking 31% of the targets. During the first 24 hours, 30 F-117As struck 37 high-value targets effectively shutting down Iraq's Integrated Air Defence Systems (IADS) and all but eliminated its ability to conduct a co-ordinated war against the coalition forces.

By the end of the conflict F-117As, which had represented less than 2% of the coalition's tactical strike assets and flew less than 1% of the total sorties, were responsible for striking around 40% of the strategic targets. The Nighthawks achieved a remarkable 75% direct hit rate, while maintaining an 85% mission capable rate.

The F-117As remained in Saudi Arabia until April 2, when the first group of eight aircraft returned to Nevada. Detachments of six to eight stealth fighters continued to support rotational deployments to the region as part of the 4404th Composite Wing (CW) until February 1994 when the last F-117As returned from Saudi Arabia. Although the missions were called off, the aircraft were prepared for combat sorties on at least two occasions in September 1991 and August 1992. Six F-117As were however, launched for a strike that targeted the Al-Amara Integrated Operations Center (IOC) and an SA-3 site in Ash Shuaybah and radar sites in Nasiriya and Basra on January 13, 1993.

The Nighthawks began relocating to Holloman AFB, New Mexico, where they were reassigned to the 49th Fighter Wing. On May 8, 1992, the initial moves took place, when 20 aircraft were assigned to the 416th FS departed Tonopah. The 417th FS flew eight F-117As to Holloman on June 15 and 13 aircraft from the 415th FS followed on June 30. Another flight of seven aircraft from the 415th departed on July 6 and the 49th FW assumed the full responsibility for the stealth mission that same day. The last F-117A left Tonopah on July 8 when the 37th FW was inactivated.

Five additional Nighthawks were receiving depot maintenance and flew directly to Holloman when those efforts were completed. The wing's 416th and 415th Fighter Squadrons were respectively redesignated as the 8th and 9th Fighter Squadrons in July 1993. Subsequently in December 1993, the 417th was redesignated as the 7th Fighter Squadron.

Southern Watch

F-117As were deployed in support of Operation Southern Watch on at least two occasions. On September 12, 1996

Above: ***Stealth pilots reckoned their most important piece of personal kit was a Sony Walkman. Listening to music between the Iraqi border and King Khalid AB relaxed them after a dangerous, pressure-packed bomb run over a heavily defended target. Many tuned in on the long flight from the US to Saudi Arabia during Desert Shield.***

Below: ***Maj Joe Bouley gives a thumbs up to the ground crews as he taxies out for an early night mission. His aircraft was on its 22nd sortie over Iraq at the time.*** *Both Rose Reynolds via Warren Thompson*

two groups of five F-117As launched from Holloman and with the help of 15 aerial refuelling events each, flew directly to Ahmed Al Jaber Air Base, Kuwait. The deployment followed the launch of an Iraqi SA-6 SAM at a USAF F-16 that had been patrolling one of the two UN-mandated no-fly zones over Iraq on September 11. On November 21, 1997, six aircraft operated by the 8th FS arrived at Ahmed Al Jaber Air Base. A second group of six F-117As, operated by the 9th FS arrived at the base in mid-February. While deployed, the Nighthawks did not participate in any air strike and the two squadrons respectively returned to Holloman in February and June 1998.

Desert Strike

F-117As were deployed to Ahmed Al Jaber Air Base, Kuwait in mid-September 1996 following the Operation Desert Strike cruise missile attacks against Iraq that happened on September 3, 1996. Eight aircraft flown by the 9th FS arrived at Al Jaber on September 13 and on December 1, members of the 8th Fighter Squadron replaced the 9th, but continued to operate the former's deployed fighters. The Nighthawks returned to Holloman in February 1997 without seeing action. In all, the 8th and 9th flew 722 sorties totalling 1,482.6 hours while deployed.

Desert Thunder

On November 18, 1997, the 49th FW received official notification of another deployment to be carried out in response to threats by Iraq's President Saddam Hussein to violate a no-fly zone set up over the country and to shoot down USAF U-2 reconnaissance aircraft. Ten F-117As flown by the 8th FS departed Tonopah less than 24 hours later on November 19. They stopped overnight at Langley AFB, Virginia, and the six primary fighters departed there on November 20.

The 8th FS personnel were relieved by the 9th FS, which deployed on March 19, 1998. In the first two months of the deployment aircrews flew 240 sorties for 376.6 hours. The unit remained in theatre until June 6 when the first of six F-117As departed Al Jaber. A second group of six stealth fighters left the following day and ten aircraft arrived at Holloman AFB on June 10. The final pair followed three days later.

The 12 Nighthawks flew an overall total of 1,150 sorties during the nearly seven-month deployment.

Above: ***In a rare daylight flight, an F-117 flies over a Saudi resort north of Khamis Mushait. The sortie is probably a check ride following maintenance. Located three hours' flying time from the Iraqi border, this area was deemed safe from any attack from the air or ground.*** *Rob Donaldson via Warren Thompson*

Desert Fox

On December 19, 1998 a four-day bombing campaign struck targets in Iraq as part of Operation Desert Fox. Although ten F-117As had departed Holloman AFB on November 14, only four had reached Europe when the deployment was cancelled. The Nighthawks remained at Morón Air Base, Spain, until December 20 when they were ordered back to New Mexico.

Above: ***About two weeks after Desert Storm started, the 37th TFW's remaining squadron, the 417th TFTS, despatched six aircraft and several pilots from Tonopah to King Khalid to help ease the demanding workload of those already in theatre.*** *Rose Reynolds via Warren Thompson*

Above: ***Col Alton Whitley took over as 37th FW CO on August 17, 1990, leaving him no time to settle in before the unit's initial deployment to the Middle East for Operation Desert Shield. He led F-117 operations throughout Desert Storm.*** *USAF via Warren Thompson*

Right: ***Facilities at King Khalid AB were built to withstand considerable punishment. The US and Saudi flags can be seen hanging from the HAS roof.*** *Rose Reynolds via Warren Thompson*

Allied Force

On February 20, 1999 12 F-117As from the 8th FS deployed to Aviano Air Base, Italy, in support of Operation Noble Anvil. They were assigned to the 31st Air Expeditionary Wing as the 8th Expeditionary Fighter Squadron (EFS). The aircraft conducted their first air strikes against Yugoslavia on March 24, 1999 in support of NATO's Operation Allied Force, which was launched in response to Serbian President Slobodan Milosevic's campaign of ethnic cleansing of Kosovar's Albanian Muslim population.

The only combat loss suffered by the F-117A fleet occurred on March 27, 1999 when serial 82-0806 was shot down by a Russian-made SA-3 surface-to-air missile (SAM) around 30 miles (48km) west of Belgrade. A second group of Nighthawks arrived in Europe on April 4, when 13 aircraft from the 9th FS touched down at Spangdahlem Air Base, Germany. One of the aircraft was subsequently flown to Aviano as a replacement for serial 80-0806, which was lost on March 27.

Operating as the 9th EFS, and assigned to the 49th Expeditionary Operations Group, the Spangdahlem Nighthawks launched their first mission just 33 hours after arriving in Germany. By late May 1999, F-117A operations were consolidated at Spangdahlem and NATO suspended air attacks against Yugoslavia on June 10 after 78 days of bombing. Throughout the 11-week air campaign NATO forces conducted more than 34,000 sorties. The 26 F-117As that had deployed combined to fly 743 sorties.

By June 22, the US Secretary of Defense ordered all the deployed Nighthawks to return to Holloman. Two groups of 11 F-117As arrived back in New Mexico on June 26 and June 29 and the final pair followed on June 30.

During the air campaign the F-117As utilised a previously undisclosed non-lethal weapon, know as the BLU-114/B. This munition was used to attack Serbia's electrical power grid on May 2, and again on May 7, 1999. The weapons disabled 70% of the power grid. Known as a 'soft bomb' or a graphite bomb, the BLU-114/B is detonated over its target and disperses a large number chemically treated carbon filaments over electrical components that cause a short circuit and knock out power.

Above: ***Leading a trio of F-15E Strike Eagles, an F-117 from the 8th Expeditionary Fighter Squadron prepares to launch from a forward-deployed air base in the Middle East on April 14, 2003 during Operation Iraqi Freedom.*** *USAF*
Below: ***An F-117 from Holloman AFB, awaits a last-chance inspection by the ground crew prior to heading out for another strike mission during Operation Southern Watch.*** *USAF*

Iraqi Freedom

Like Desert Storm, F-117As were called upon to conduct a surgical strike prior to start of Operation Iraqi Freedom, which began on March 20, 2003. Deployed by the 49th FW at Holloman, the Nighthawks were assigned to the 379th Air Expeditionary Wing and operations were conducted from Al Udeid Air Base, Qatar. The lead-off mission involved two Nighthawks that were tasked to target an underground bunker in the Dora Farms complex near the Tigris River southwest of Baghdad, where Saddam Hussein and his sons were believed to be spending the night.

The mission was launched with just four hours' notice and was assigned to the 8th Expeditionary Fighter Squadron. Four 2,000lb EGBU-27 Paveway III penetrating bombs were to be delivered against the target. The F-117A had been cleared to drop the weapon just hours before the mission went off. In addition to its laser guidance, the EGBU-27 was capable of being guided to its target via GPS/INS guidance and could be delivered to an exact series of co-ordinates after its release. Although this mission marked the first use of the EGBU-27, by the time combat operations ended F-117As had delivered 98 of the weapons compared with just 11 of the standard GBU-27s.

A second wave of F-117As hit key targets as part of a strike designed to knock out Iraq's air defences and C3 capabilities. Unlike Desert Storm, which saw the deployment of 42 Nighthawks, just 12 F-117As were called up for Iraqi Freedom. F-117s flew 87 combat

Above: ***The mere presence of F-117s in the region has often been enough to deter an aggressor from conducting any provocative action. This was the case in Korea when F-117s deployed to the south and military threats from the north stopped until the stealth aircraft had left the region.*** *USAF*

sorties in support of the operations and the Nighthawk demonstrated a mission capable rate of 89.3%. The initial group of 8th FS Nighthawks deployed to Al Jaber on February 3 and by February 4, 12 aircraft had arrived. As a result of the short duration of sustained combat operations, five of the 12 'black jets' flew back to Holloman on April 16, 2003. The remaining seven F-117As returned home on April 21.

Nighthawk retirement

On March 17, 2007, retirement of the F-117A began when an initial group of seven Nighthawks was flown from Holloman to Tonopah where they were placed in long-term storage. Operations at Holloman came to a close on April 21, 2008 when the last four F-117As departed. Test and support operations continued from Lockheed's Palmdale facility, until August 11, 2008 when the final Nighthawk departed for Tonopah.

The retirement of the Nighthawk was part of Program Budget Decision 720, which was released on December 28, 2005. The Air Force Transformation Flight Plan outlined the service's proposal to save more than US$21bn between 2007 and 2011, and direct those funds into programmes that would make the USAF a "more lethal, more agile, streamlined force with an increased emphasis on the warfighter".

The service had originally planned to retire the 52 aircraft in 2011, but PBD 720 pushed the implementation forward so it would begin in 2007 and conclude in 2008.

Although the last Nighthawks were retired in 2008, the bulk of the fleet has been maintained in Type 1000 storage at the Tonopah Test Range, as required by direction within the Fiscal Year 2007 National Defense Authorization Act (NDAA), the provision required that any F-117A retired after September 30, 2006 be maintained in storage.

According to the USAF: "Aircraft in Type 1000 storage are to be maintained until recalled to active service, should the need arise. Type 1000 aircraft are termed inviolate; meaning they have a high potential to return to flying status and no parts may be removed from them. These aircraft are 're-preserved' every four years."

Since retiring in 2008, the Nighthawks have been maintained in their original, climate-controlled hangars. However, as a result of the storage requirements, there have been several sightings of Nighthawks in the air being reported in recent years. According to the USAF, this is because occasional F-117 flights are required in order to confirm the effectiveness of the flyable storage programme.

Although the Fiscal Year 2017 NDAA is far from being approved, the version of the bill that was approved by the US House of Representatives, and prepared by the House Armed Services Committee (HASC), includes a provision that repeals the requirement to preserve the F-117 fleet and would allow the USAF to finally divest itself of the Nighthawks.

Has the end finally come for the famous 'black jet'? Only the politicians know...and only time will tell.

Above: ***Upon their return to Holloman AFB, after Operation Iraqi Freedom, F-117s wore mission markings showing successful strikes.*** *USAF*

Above: ***Overnight on March 27/28, F-117 82-0806 was shot down 40 miles(64km) from Belgrade, Yugoslavia while participating in Operation Allied Force.*** *Serbian Air Force*

Below: ***F-117s were to return to the Arabian Gulf a number of times, following their combat debut in 1991, to conduct surgical strikes against targets in Iraq. This example had just flown a successful attack against an Iraqi command bunker on March 20, 2003 as part of Operation Iraqi Freedom.*** *USAF*

F-117A Upgrades

Tom Kaminski describes the upgrades that kept the F-117A viable during its relatively short frontline career.

***Above:** Upgrades introduced across the F-117 fleet kept the aircraft operating into the 2000s – among them was this example serving with the 9th Fighter Squadron 'Flying Knights' at Holloman AFB, New Mexico. Surprisingly, none of the F-117s were deployed to the Middle East after the 9-11 terrorist attacks or played any part in Operation Iraqi Freedom in 2003 which removed Saddam Hussein from power.* Richard Cooper
***Right:** The F-117 cockpit as it appeared upon completion of the Offensive Capability Improvement Program (OCIP) which added a moving map display and replaced the Texas Instruments displays with Honeywell colour units. Underneath the HUD is a large display screen for infra-red imagery and beneath that is the main communication panel. On the left-hand console are the aircraft systems controls, and on the right are the navigation and communications controls. The two side handles on the seat initiate the ejection sequence.* Don Logan

IN CONTRAST WITH most recent military aircraft the F-117A, because of its comparatively brief period of operational service, received a small series of updates that was generally aimed at improving maintainability and reliability.

In addition to at least seven minor configuration updates first implemented from October 1983, several more complex upgrades were carried out under the three-phase Offensive Capability Improvement Program (OCIP).

Carried out under OCIP Phase I, first was the Weapons System Computational Subsystem (WSCS) upgrade. It replaced the Nighthawk's three Delco M362F mission computers with a single IBM/Loral AP-102 and integrated the 2,000lb bunker-busting GBU-27 Paveway III laser-guided bomb that was used extensively during Operation Desert Storm. The upgrade was approved on April 1, 1984 and delivery of modified aircraft took place between November 1987 and June 1992.

The F-117A received a new cockpit layout under OCIP Phase II. A digital moving map display replaced the original forward-looking infrared/downward-looking infrared (FLIR/DLIR) display. The infrared imagery was now shown on a pair of Honeywell colour multifunction liquid crystal displays (LCDs), which replaced the original Texas Instruments monochrome multifunctional displays (MFDs). A new data-entry panel enabled the pilot to select from 256 avionics functions.

In addition, the aircraft received a four-axis flight management system that connected the autothrottle, autopilot and navigation system, and enabled automatic flight to a precise location at a specified time. In addition, a pilot-activated automatic recovery system (PAARS) was incorporated. When activated, it returned the aircraft to straight-and-level flight and was reportedly developed specifically in response to several fatal accidents that involved controlled flight into terrain (CFIT).

Test aircraft 85-0831 first flew the OCIP II modifications with the 410th Flight Test Squadron (FLTS) at Palmdale, California, on December 1, 1988. The first production modification kit was installed in April 1990 and the last upgraded aircraft was completed on March 8, 1995.

Under OCIP III's Ring Laser Gyro Navigational Improvement Program (RNIP), a new Honeywell H-423/E laser inertial navigation system (INS) replaced the F-117A's Honeywell SPN-GEANS INS, which had originally been developed for the B-52G bomber. The subsequent RNIP+ integrated a Rockwell Collins GPS with low observable antennas, which provided continuous aircraft position accuracy within 30ft (9.1m), without the need for ground navigation aids.

Begun in 1991, the $100m upgrade greatly improved navigation and targeting accuracy while also increasing system reliability and reducing maintenance requirements. The USAF expanded the programme in May 1993, when it decided to replace the control display navigation unit (CDNU), incorporate the GPS and upgrade the aircraft's weapon system computers with increased memory and processing speed.

The first development aircraft flew at Palmdale in December 1994 and Lockheed Martin delivered the initial RNIP+ F-117A, upgraded under OCIP Phase III, to the 49th Fighter Wing at Holloman AFB, New Mexico, on January 24, 1997.

IRAD upgrades

The F-117A's original Infrared Acquisition and Designation System (IRADS) was upgraded under a Block 1 modification that replaced circuit boards and rerouted wiring, between 1986 and 1988. Beginning in 1993, new Texas Instruments thermal imaging sensors replaced the original FLIR and DLIR sensors. Known as the F3 turret, the new equipment was first tested on August 14, 1992. The installation of production turrets began in October 1994 and was completed in October 1996.

The Single Configuration Fleet (SCF) made improvements to the aircraft's RAM coatings and their application and processes. Development began in June 1996, and the conversion of operational aircraft started late in 1999.

Begun in 1998, the Stores Management System Processor (SMP) upgrade integrated a MIL-STD-1760 weapons data bus that enabled the carriage of newer munitions, including the 2,000lb EGBU-27. This added GPS/INS guidance to the GBU-27's laser guidance system. The SMP upgrade also equipped the Nighthawk to deliver Joint Direct Attack Munitions (JDAMs) and Wind Corrected Munitions Dispensers (WCMDs).

The Smart Weapons Integration project began in 2004, and the first JDAM separation tests were flown on January 21, 2004, when Block 2 weapon system software was used to deliver two 2,000lb GBU-31s at Edwards AFB, California. The capability became operational in 2006.

Over its production and service life, numerous other modifications were made to the Stealth Fighter. These included upgrades to the engine exhaust system, the incorporation of carbon-fibre brakes, graphite thermoplastic composite fins, composite weapons bay doors and an improved low-probability-of-intercept secure communications system that enabled the aircraft to transmit/receive data via an encrypted data link.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SAY DOOR
FUEL QUANTITY
FLIGHT CONTROLS
CAUTION SPRING LOADED PILOT CHUTE

Raptor Goes to War

Tim Ripley looks at the combat debut of the F-22A Raptor in the war against Daesh in Syria and Iraq.

FOUR USAF F-22A Raptors took off to lead an airborne strike force into the heart of the Daesh's capital in northern Syria on the night of September 22-23, 2014.

Although the jihadi groups were also fighting the government in Damascus, no one in the US Air Force-run Combined Air Operations Centre (CAOC) in the Middle East, was sure how the Syrian Air Force and integrated air defence network would react to this incursion into their airspace by USAF and allied aircraft.

It was not the time to take any chances, so US air commanders ordered up America's most capable combat jet to take the lead. The F-22As would fly deep into northern Syria, utilising their unique stealth capabilities to keep the Syria air defences guessing about the position and intentions of the US-led strike force.

For the next 18 months, the F-22As remained in the Middle East to spearhead continuing US-led air strikes into Syria and Iraq, as well as playing cat and mouse with Russia's Sukhoi new super fighters, which appeared over Syria in September 2015.

Raptor Work-up

The combat debut of the F-22A over Syria was the culmination of more than two decades' effort to build and bring the Raptor into service. As the America's first fifth-generation combat aircraft, which brought true stealth, or low-observable capabilities, to the USAF's air-supremacy community, it was not a surprise that it would be committed to action in the Middle East.

***Above:** A Daesh command and control facility demolished by JDAMs dropped from F-22s on the first night of the US air campaign over Syria.*

After a 15-year design-and-build programme at Lockheed Martin's Marietta plant in Georgia, the air force declared the Raptor's initial operational capability in 2005. There then followed three years of air and groundcrew training, which culminated in global deployment exercises, mainly to US bases on Guam and Japan, to build up experience and expertise to operate the F-22A far from home bases.

The first Raptor deployment to the Middle East took place between November and December 2009, when four F-22As flew to Al Dhafra Air Base in the United Arab Emirates to take part in a tactical leadership exercise, flying simulated combat missions against allied air forces. The event later achieved notoriety when French Air Force Rafale pilots released gunsight images purporting to show a Raptor being shot down in a simulated dogfight.

The USAF Raptor fleet was then hit by a series of safety scares linked to the aircraft's oxygen supply failures and it was not until April 2012 that F-22As returned to the Middle East. Tension with Iran was rising because of the country's nuclear programme, so the USAF wanted its best fighters in region in case they had to go head-to-head with the Iranian Air Force's F-14 Tomcats and MiG-29s.

Strategic deterrence was the name of the game for the F-22As on the Middle East deployment and the Raptor squadrons took turns to sustain a continuous presence at Al Dhafra. In 2013, a Raptor was dispatched to act as an escort for an MQ-1 Predator unmanned aerial vehicle on patrol over the Arabian Gulf. Two F-4 Phantoms were approaching the US drone when the Raptor swung into view and sent the Iranian pilots heading for home, with their tails between their legs.

First Strike

Fast-forward to September 2014 and US air power had now been turned against Daesh fighters attempting to seize control of Syria and Iraq. Their advances into Iraq were threatening the capital Baghdad and then the Kurdish region in the north of the country. USAF F-15E Strike Eagles and US Navy F/A-18E Hornets began bombing militant fighters in August and brought the enemy spearheads to a halt. The Raptor crews at Al Dhafra were not called upon to participate in the early raids because Daesh did not have any meaningful air defences with their frontline troops. Attention now turned to how to hit the jihadi group's 'capital' in the Syrian city of Raqqa in a bid to undermine its command and control structure and logistic networks.

During early September 2014, planners at the CAOC at Al Udeid Air Base in Qatar were working up plans for the strikes into Syria, but this was carried out in great secrecy. At Al Dhafra Air Base, the Raptor crews of the 27th Fighter Squadron were making their final preparations to return to their home base at Langley, Virginia, after nearly six months' on desert duty. Long-range drop tanks were already fitted to their jets for the flight back across the Atlantic and the first replacements pilots and maintainers from Tyndall AFB in

The F-22 Raptor has taken over from the F-15E Strike Eagle as the USAF's premier fast jet strike asset.
All images USAF unless stated

An F-22 of the 1st Fighter Wing refuels over Baghdad on its return from the first strike against Daesh targets in Syria.

Florida had already started to arrive.

Then then word came from the CAOC that the Raptor would lead the strike on Syria and the 27th FS's Squadron's personnel had rapidly to change gear. Within 24 hours airmen had removed the drop tanks and two 1,000lb Joint Direct Attack Munitions (JDAMs) loaded in the jet's weapons bays, along with AIM-9 Sidewinder and AIM-120 air-to-air missiles.

"It was awesome to see the [maintainers] work and get the jets reconfigured. Then we kind of sat in that mode, not sure if we were going to execute or not," one of the F-22A pilots involved in the mission recounted in a report produced by the air power advocacy group for the Air Force Association (AFA), in co-operation with the USAF.

Meanwhile the 27th Squadron's pilots began their initial planning and then, 24 hours before take-off, they received details of their target, a Daesh command and control facility in northern Syria.

USAF Maj Gen Jeffrey L Harrigian, Assistant Deputy Chief of Staff for Operations, Plans, and Requirements on the Air Staff, said it made sense to use the F-22As. Airspace was highly defended and for the first couple of nights the USAF needed to understand how the Syrian integrated air defences worked.

The Raptor aircrews had spent some six months leading up to the initial air campaign studying Syria's surface-to-air missiles and aircraft.

A pilot quoted in the AFA report said: "We would try to generate all of our scenarios around those specific mission sets. A lot of our training when we got in theatre was focused specifically on countries we were concerned with: Iran and Syria."

The CAOC planners had developed attack plans based around three waves of cruise missiles and strike aircraft. The first wave of Tomahawk cruise missiles launched from US Navy warships in the Red Sea and Arabian Gulf would hit their targets around Aleppo and Raqqa at 0230hrs (local time) on September 23.

Half-an-hour later a wave of USAF F-15Es, F-22As and United Arab Emirates Air Force and Air Defence F-16E/Fs, backed up a USAF B-1B Lancer, were scheduled to hit targets around Raqqa. Then, at midnight, another wave of USAF F-16Cs and US Navy F/A-18E/Fs would hit targets in eastern Syria, around the city of Deir Ezzor. That, at least, was the plan. During the course of the evening, the F-22A pilots would play a major part in making sure the strike would succeed.

The strike force was readied at Al Dhafra during the early evening and three cells,

'The F-22As would fly deep into northern Syria, utilising their unique stealth capabilities to keep the Syria air defences guessing about the position and intentions of the US-led strike force.'

RAPTOR GOES TO WAR

each of four strike aircraft, were poised to roar down its desert runway. Each cell had a strike jets had a KC-10 Extender tanker attached to refuel them during the 1,200-mile flight to their targets. The heavy tankers had already departed and were heading northwards to their tracks over Iraq.

As is common at the start of a major operation, groundcrews across the base were looking forward to the imminent action.

"The weapons folks don't often get a chance to load live munitions on the Raptor, so those guys were out there, very excited," said an F-22A pilot. "We had four weapons crews total and three of the four were out there on the line. All of them wanted to be out there."

Just as the operation was getting under way, disaster struck and the first F-15E to launch suffered an engine problem and aborted its take-off, blocking the runway for the whole strike package for 20 minutes.

Playing Catch Up

Once the strike force was able to launch, the pilots worked hard to make up for the delay to achieve their times-on- targets (TOTs). First they had to link up with their tankers to take on fuel. It had been intended that the F-22As, which had launched last, would overtake the F-15Es and F-16E/Fs. The jets then hit headwinds over Iraq, which further delayed them. When Iraqi air traffic controllers mistakenly instructed the jets to head east towards Iran, some of the Raptor pilots wondered if they would ever make it to their targets.

"Just because our airplane was intended to do other missions, it doesn't mean we can't adapt, innovate and become more relevant to the current fight.

At last the jets hooked up with their tankers over central Iraq and the pilots could turn their attention to pushing into Syria.

Another of the F22 pilots said: "Even going direct [to the target], I wasn't going to make it unless I started going much, much faster."

The F-22 pilots then turned on their afterburners, accelerating to Mach 1.5, and began to climb to 40,000ft. "We were pulling the power back to try to keep the jet from accelerating past 1.5 because 1.5 was actually the sweet spot for us to hit the time on target exactly on time," said a pilot.

The strike plan called for the F-22As, F-15Es and F-16E/Fs to hit their targets simultaneously, but the Raptors would hit the furthest west targets, making them the most exposed cell. Meanwhile the Lancer, flying independently from Al Udeid, would hit other targets in northern Syria.

Syncing the Strikes

"My two-ship was the first in the country and the farthest into the country at that point. We were the leading edge, making sure there was no air threat for the follow-on package," said one of the pilots.

"Then my three and four would follow up in that max-range airspeed and they would hang out as long as possible to ensure we have 'actors on station' in case Syria launched any airplanes.

"It was obvious when we got about halfway through Syria that [their air force was] not going to respond to us," recalled the Raptor pilot.

This did not mean the strike force could let its guard down. The F-22As were required to remain in Syrian air space until all the strike aircraft were clear, using their radars and other electronic sensors to sweep for signs of Syrian threats.

The mission was now going well, with the first two F-22As dropping their JDAMs within five seconds of the desired TOT and all the weapons hit their targets. At a Pentagon briefing the following day, video imagery was shown of the GPS-guided weapons devastating large buildings.

The night's work was not over the F-22A pilots. They still had to provide cover for the non-stealthy strike jets. The third and fourth Raptors remained on patrol for an hour, while the F-15Es and F-16E/Fs did their work and exited Syrian air

F-22s formate over Al Dhafra AB in the UAE, which has been the forward operating location for the jets since 2009.

space. Meanwhile, the first pair of F-22As refuelled from a tanker over Iraq, before returning westwards to cover the egress of the last pair of Raptors. The idea was that the stealth fighters would have continuous surveillance coverage throughout the mission.

According to another of their pilots, "It was a relatively uneventful night. We saw a lot of flashes with [night-vision goggles] as the bombs were going off in various target areas, but we didn't see a whole lot of action from Syria or their ground forces," said one of the pilots. "It looked like the vast majority of the action was coming from the coalition bombs."

Escorting Lancers & UAVs

Throughout the mission US intelligence assets, including surveillance satellites, MQ-1 Predator and MQ-9 Reaper drones were monitoring the targets to allow controllers in the CAOC to make real-time bomb damage assessments. Planners in the CAOC now determined that some of the Tomahawk strikes around Aleppo had not had the desired effect. The B-1B bomber needed to be quickly directed to re-strike the targets. Controllers on USAF E-3C AWACS aircraft began working out how to get the Raptors to turn around and escort the B-1B back into Syrian air space.

As this was unfolding the four Raptors were just to the west of Iranian airspace and trying to find a tanker to top off their tanks to make it back to Al Dhafra. "Gas is always my biggest concern," recalled one of the F- pilots. "We had looked at the fuel plan early on and we knew that there was extra gas available for contingencies, but we were completely off the script now, so I had no idea where the tankers were."

The AWACS controller informed the pilots there was a KC-135 "over [near] the Iranian border" with enough fuel for them to top off. As they received these instructions, two of the pilots were briefed on the details of their new mission. The new target was the furthest point west so far for the Raptors that night.

***Above:* Bomb damage assessment imagery of targets struck by F-22s on the opening raids into Syria.**
***Below:* A 1st Fighter Wing F-22 takes off from Al Dhafra AB in the UAE.** *Antonio Muñiz Zaragüeta*

By the time the F-22As left the KC-135 along the Iranian border, the third wave of strike jets was beginning to hit its targets in eastern Syria, so the F-22s and B-1B had to climb high to keep above the other jets.

The Raptors provided air coverage for the B-1B for another 30 to 45 minutes before refuelling for a third time and then heading home.

Multi-Tasking

One of the four Raptor pilots said: "There was a lot going on in the mission, a lot to deal with, a lot of changes and contingencies that I didn't have to deal with in my previous combat experience, as limited as it was," said an F-22A pilot. "It was a great experience."

The Raptors arrived back at Al Dhafra just after dawn had broken, as CAOC intelligence analysts were poring over video imagery from the strikes. Within hours these pictures would be broadcast during a media briefing at the Pentagon.

For the pilots and ground crews at Al Dhafra there was work to do. The jets had to be turned around for the next day's strikes, new missions planned, and rest to be taken. Over the next three months the F-22As from the 27th Squadron and their replacements from Tyndall's 95th Fighter Squadron flew nearly 100 combat missions over Syria.

Long War

Raptor squadrons from the active duty USAF, Air Force Reserve Command and

An F-22 being waved off for a night mission over Syria from Al Dhafra AB.

RAPTOR GOES TO WAR

Air National Guard now settled into steady ops tempo to sustain Operation Inherent Resolve. Every six months a new Raptor squadron would take its turn on duty at Al Dhafra, deploying six jets and between 150 and 200 aircrew, operations and maintenance personnel. Each squadron deployment would be made up of a mix of active and reserve personnel from each of the four F-22A homes bases.

For the first year of the conflict, the F-22As would bear the brunt of manned strikes into the far northwest of Syria. But as it became more apparent that the Syrian Air Force was not going to challenge the US-led intervention against Daesh, the F-22A crews found themselves tasked for many other missions, including close air support (CAS) for allied troops and militia fighters under attack.

Typical of these was a mission in June 2015, when pair of F-22 Raptors flying over Syria received a nine-line (CAS) request for short-notice airstrikes from a US Special Forces Joint Terminal Attack Controller working with anti-militia fighters.

The JTAC's target was two field artillery pieces operated by Daesh threatening friendly forces. A Reaper drone was already on the scene and pinpointed the location before passing the co-ordinates to the F-22As. Within minutes, the Raptors each released multiple satellite-guided, small-diameter bombs on the targets, destroying them in close proximity to friendly forces.

Weeks later, another pair of F-22As flying over Iraq executed a similar short-notice airstrike, releasing two GBU-32 JDAMs, destroying two enemy fighting positions in Al-Anbar Province.

"Since 2005, F-22A training has focused on our primary missions: air-to-air combat and precision strikes against highly defended ground targets," said Lt Col J, the then Squadron Commander of the F-22A squadron at Al Dhafra.

"However, ten years later, the F-22A's air-to-ground capabilities are more robust, CAS procedures have evolved to incorporate advances in technology, and this operational environment is different from that which we

***Above:** Ground crews prepare F-22s for missions over Syria beneath the sunshades at Al Dhafra AB in the UAE. Ground crews prefer to work at night because of the high temperatures at the Gulf base.*
***Below:** An F-22 breaks off after refuelling from a USAF tanker before heading into Syrian airspace to strike at Daesh logistical and transportation targets.*

envisioned in 2005. Before deploying, we kind of anticipated we might find ourselves in a situation to provide CAS out here.

"Just because our airplane was intended to do other missions, it doesn't mean we can't adapt, innovate and become more relevant to the current fight. Our goal is to provide the air and ground commanders [with] the effects they need today. I believe we can do that without sacrificing our core competencies," he added.

Maj J, an F-22A pilot, said: "Moving into this fight, there was a certain language that we [in the F-22A community] didn't speak. Being a

Raptors from Al Dhafra AB led the first wave of night-time strikes against Daesh militants in September 2014.

former JTAC, I had knowledge that I used as building blocks to teach my fellow pilots the terminology and the nine-line system. From there we transitioned to real-world training scenarios and then moved to executing it in combat. It was extremely fulfilling to see how this training enabled F-22As to support coalition ground forces in combat."

That training proved invaluable during the first F-22A CAS strikes flown, said one of the F-22A pilots involved in the CAS missions.

Capt E commented that the CAS missions were good for the morale of the Raptor pilots because they were directly contributing to fight. "Every time I take off, I want to drop bombs and make a positive impact out there. And this is merely another way we've discovered of enabling that," he said.

Lt Col J stated: "Frankly, most combat aircraft in the US inventory can perform this particular role, especially in a semi-permissive environment. It's about being innovative and adjusting to the unique situation we've found ourselves in".

"We can provide these effects while we are already accomplishing our core air dominance mission; it's a win-win. It's about using the capabilities you have and adapting them to help your team win the current fight."

The Russians Arrive

The arrival of the Russian Air Group in Syria in September 2015 dramatically changed the dynamics of the Syrian war. Suddenly there were three dozen high-performance Russian Sukhoi Su-24s, Su-25s, Su-30s, Su-34s and Su-35s plying their trade over Syria.

The US and Russian governments moved quickly to try to reach an agreement to ensure that their air forces did not accidently fly into or target each other over Syria. A hotline was established between the CAOC in Al Udeid and the Russian Air Command Centre at their airbase in Syria's Latakia province.

A procedure was devised to deconflict US-led and Russian air operations, establishing ➤

"Every time I take off, I want to drop bombs and make a positive impact out there."

ORDER OF BATTLE USAF F-22 RAPTOR FORCE & DEPLOYMENTS, 2009-2016

Base	Wing	Sqns	Role
Air Command Command			
Langley AFB, Virginia	1st Fighter WG	27th Fighter Sqn	
		94th Fighter Sqn	
	192nd WG	149th Fighter Sqn (Virginia Air National Guard)	
Tyndall AFB, Florida	325th FW	95th Fighter Sqn	
		43d Fighter Sqn	FTU
	44th FG	301st Fighter Sqn (Air Force Reserve Command)	
Nellis AFB, Nevada	53rd WG	422nd Test and Evaluation Sqn	
Nellis AFB, Nevada	57th WG	433d Weapons Sqn	
Holloman AFB, New Mexico	49th Fighter WG	7th Fighter Sqn*	
		8th Fighter Sqn**	
		301st Fighter Sqn (Air Force Reserve Command)***	
Pacific Air Forces			
Elmendorf AFB, Alaska	3rd WG	90th Fighter Sqn	
		525th Fighter Sqn	
	477th FG	302d Fighter Sqn (Air Force Reserve Command)	
Hickam AFB, Hawaii	15th WG	19th Fighter Sqn	
	154th WG	199th Fighter Sqn (Hawaii Air National Guard)	
Air Force Materiel Command			
Edwards AFB, California	412th Test WG	411th Flight Test Sqn	

de-activate 2014, **de-activate 2011, * move to Tyndall AFB 2014*

USAF KC-10 Extenders provide extensive air-to-air refuelling support for F-22 strikes.

Right: Baghdad at night. Raptors heading into Syria were often refuelled over the Iraqi capital by USAF KC-10 and KC-135 tankers.
Below: Conventional non-stealthy aircraft, including US Navy F/A-18 Hornets, are regularly paired with F-22s to maximise the stealth capabilities of the Raptor.

separation blocks of air space. However, it will come as no surprise that the Russians and Americans were keen to use the opportunity to get a close look at each other's most advanced aircraft.

According to USAF F-22A Requirements Officer, Maj Justin Anhalt, the Russians appeared keen to find out as much as possible about the Raptor.

He said Syrian and Russian pilots were interested in the F-22A, and may have tried manoeuvring close to the American jet to see how it operates, but "because of our sophisticated avionics and stealth and supercruise and manoeuvrability," there was "not a time when we allowed the Syrians or Russians to see us or influence us in any way," he explained.

He said there were "some incidents early on" in which F-22As had to steer coalition air packages away from the Syrian or Russian jets and "we were very close to them and they never realised it".

He stressed the importance of the F-22A in what he termed the 'quarterback role', working to choreograph air operations at a tactical level, to make sure the right people are in the right place at the right time.

"In this type of environment we're keeping everyone safe", he said. "We're keeping [coalition aircraft] away from Syrian aircraft and Russian aircraft and we continue to make sure things are de-escalated."

Combat Raptor Assessed

More than ten years after it formally entered USAF service, the F-22A Raptor is proving its worth in combat in the skies over Iraq and Syria.

The head of the USAF's Air Combat Command, General Herbert J 'Hawk' Carlisle, told the AFA's Air and Space Conference in September 2015 that the F-22A: "Is even better than we thought it was. It does more than we even thought it could do."

He added the Raptor was now indispensable in the fight against Daesh and the F-22As "enable [the coalition's

"The F-22A's advanced sensors and low-observable characteristics enable us to operate much closer to non-coalition surface-to-air missiles and fighter aircraft with little risk of detection,"

Raptors deployed from Alaska's 3rd Wing, based at Elmendorf AFB, have played a significant part in sustaining the F-22 force at Al Dhafra AB in the UAE. *Antonio Muñiz Zaragüeta*

other] fourth-generation airplanes to be even better than they would be on their own. They make everybody better".

In a USAF de-briefing report on the role of the Raptor in Operation Inherent Resolve, Lt Col J said: "The F-22A's first combat strike came in September 2014. Even though that was the Raptor's first kinetic strike, F-22A's have been operational for ten years.

"[The F-22A] has been achieving effects as a strategic deterrent since it became operational in 2005. When you move an F-22A squadron into theatre, it gets noticed. The F-22 can have a profound effect even without kinetic action.

"We are operating regularly in Iraq and Syria. The F-22A's advanced sensors and low-observable characteristics enable us to operate much closer to non-coalition surface-to-air missiles and fighter aircraft with little risk of detection," he added.

According to the USAF, the Raptors provide increased situational awareness for other coalition aircraft while simultaneously delivering precision air-to-ground weapons. This enables the USAF to reduce the risk to coalition forces while mitigating exposure to civilian casualties, one of its highest priorities in this conflict.

Lt Col J said: "The Raptor can carry up to eight Small Diameter Bombs which have been successfully employed against key Daesh targets.

"It is extremely accurate from very long distances and has the lowest collateral damage potential of any weapon in our inventory. F-22A strikes also send a strategic message, reassuring our allies and hopefully dissuading any would-be adversaries."

"In addition to flying combat missions in Operation Inherent Resolve, the Raptors in Southwest Asia are prepared to provide air dominance for any future contingency operations.

"F-22As were designed to strike deep into enemy territory while clearing the airspace for follow-on forces. We are the sole platform in this theatre that guarantees air dominance for our joint and coalition partners; we take that responsibility very seriously. The F-22A is ready to go wherever we are needed. It is a weapon system with truly global reach.

"If we are called upon, we will be ready to go anywhere in the world. We'll continue to train for the high-end fight, but our capabilities are relevant in this current fight; we will continue to help our team any way we can."

Many of the USAF personnel and aerospace industry workers who toiled for decades to prepare the jet ready for active service are relieved and pleased that it is at last cutting the mustard.

Retired USAF Lt Col Johnny Johnson, who worked on Raptor's development during the 1990s, wrote to *Air Force* magazine in early 2015 about his experiences on the programme.

"There was very little reward other than another problem to solve, which was typical of all large development projects," he recalled.

"Burnout was frequent [among personnel on the Raptor programme] and morale was always an issue. But we always kept our sights on the product with the fighter pilot in focus. And what a remarkable machine it is. I am gratified knowing that the airplane is living up to the user's expectations, and its performance is validated in combat. We truly developed a fighter aircraft with the fighter pilot mind."

ORDER OF BATTLE OPERATIONAL DEPLOYMENTS TO MIDDLE EAST, 2009-2016

Date	Base	Unit	No. Jets
US Air Forces Central Command (CENTAF)			
Nov-Dec 2009	Al Dhafra, UAE	27th Fighter Sqn	6
April-Jan 2013	Al Dhafra, UAE	7th Fighter Sqn	6
Jan - May 2013	Al Dhafra, UAE	??th Fighter Sqn, 3rd Wing	6
May - Sept 2013	Al Dhafra, UAE	90th Fighter Sqn, 3rd Wing	6
Oct 2013-Mar 2014	Al Dhafra, UAE	525th Fighter Sqn, 3rd WG	6
Mar-Oct 2014	Al Dhafra, UAE	27th Fighter Sqn	6
Oct 2014-May 2015	Al Dhafra, UAE	95th Fighter Sqn	6
May-Nov 2015	Al Dhafra, UAE	94th/149th Fighter Sqns	6
Oct 2015-Mar 2016	Al Dhafra, UAE	19th & 199th Fighter Sqns	6
Mar-Oct 2016	Al Dhafra, UAE	90th Fighter Sqn	6

Left: ***Flying night-time missions from Al Dhafra AB in the UAE is standard practice for Raptor strikes against Daesh targets in Syria.***

Tacit Blue

Smooth Operator

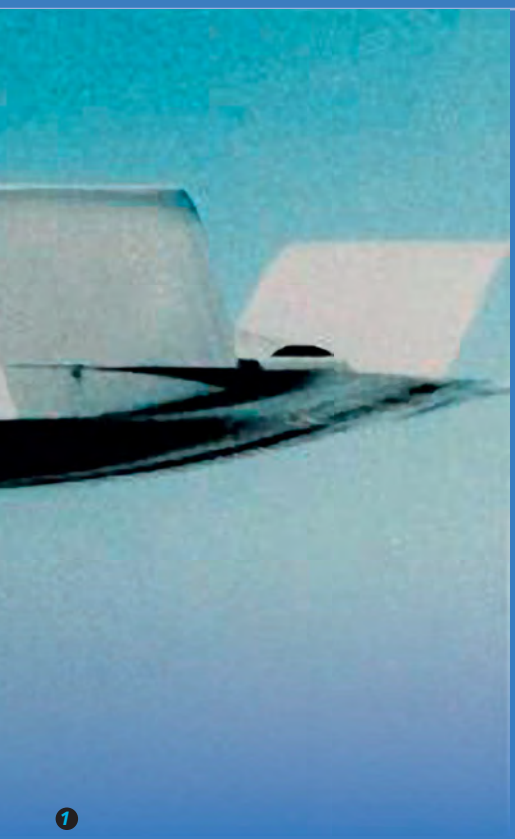
It was described as "the most unstable aeroplane man had ever flown", yet Tacit Blue, one of Northrop's declassified low observable programmes of the 1980s, has influenced the design of unmanned aerial vehicles and the future B-21. *AFM*'s **Glenn Sands** reports.

BY THE mid-1970s, computer processing and aircraft production techniques gave rise to multiple 'low observable' programmes spearheaded by a select number of US manufacturers. While those at Lockheed Martin introduced the Have Blue, which led to the F-117A Nighthawk, there was another, less glamorous, but far more secret technology demonstrator under way called Tacit Blue.

It was dubbed the The Whale among those cleared to work on the special access programme in a corner of Northrop's classified Hawthorne production facility in California. Engineers had a completely different set of objectives than Lockheed's proposed stealth attack aircraft, although reducing radar cross section(RCS) returns was the only element both projects had in common.

Lockheed utilised its Echo One radar predictability software in the 1970s and discovered that a faceted, diamond-like structural approach was suitable for stealth tactical aircraft, where speed and agility were on the requirement list. A few years later Northrop took an almost entirely

1: Just a handful of inflight photographs of Tacit Blue were released in 1996 when the 'curtain' was pulled off the programme. USAF 2: The revolutionary phased array radar which was able to provide real-time ground moving target indicator (GMTI) intelligence. Able to peer through bad weather with ease it introduced a persistent, long-range, airborne intelligence gathering capability. Known as Pave Mover, the radar's size dictated the unusual fuselage shape of Tacit Blue. USAF 3: Northrop's use of Gaussian, surfaces that redistributed a radar beam's energy allowed a curvilinear approach to be adopted for Tacit Blue, this technique is now used on the new generation of UAVs like the US Navy's X-47B. Northrop Grumman 4: The flight deck of the Tacit Blue demonstrator used conventional dial instruments scavenged from a number of regular fighter types in order to keep the overall cost of the programme down. USAF



1

opposite route to achieve a low-observable result, with the intention of producing a platform that could counter a massive Soviet ground attack in central Europe as part of the Assault Breaker programme.

Tacit Blue would be intended to serve as an undetectable airborne command post deep behind enemy lines. Once in orbit, it would supply real-time targeting information and intelligence to battlefield commanders, as part of the Assault Breaker programme. Invading Soviet armoured divisions would be subjected to a continuous barrage of precision-guided munitions directed by Tacit Blue.

Form follows Function

The ungainly dimensions of Tacit Blue were the result of Northrop engineers discovering that the radar cross section of an orbiting surveillance platform was significantly different from those needed by a bomber. Its operational profile called for it to loiter behind the lines while flying in circles. It would be exposed to detection devices from all sides.

Another problem was fitting the radar's huge antenna into what was intended to be a relatively small aircraft simply in order to reduce its being seen visually by the enemy. Fitting the antenna into the jet called for a box-shaped structure for the fuselage. Northrop engineers would have to add stealthy wings, tail and cockpit around the fuselage and make the jet airworthy.

A veteran of Northrop's classified programmes, aeronautical engineer John Cashen stated that: "The main design was driven around trying to get this box to fly and remain manageable for a single pilot to operate."

2

Rather than use a process similar to Lockheed's Skunk Works' faceted surfaces as on the Have Blue, Northrop engineers used curvilinear, or Gaussian, surfaces that redistribute a radar beam's electrical energy. This technique was later used on the B-2A Spirit. This curvilinear approach led to a configuration that defied radar detection yet also led undisclosed Northrop sources to describe Tacit Blue as: "An aircraft that at the time was arguably the most unstable aeroplane man had ever flown."

The Whale was so unstable that it utilised a quadruple-redundant General Electric fly-by-wire control system for safety.

Northrop appointed Richard G Thomas as its chief test pilot for the Tacit Blue programme and, on February 5, 1982 he made the first successful flight at Groom Lake, Nevada in Area 51. With its low radar return signal, the aircraft quickly demonstrated that such a platform could operate close to a battlefield's forward lines without detection by the enemy's radar. It could also continuously monitor enemy forces behind the lines and provide targeting information to battlefield commanders.

A Flying Box

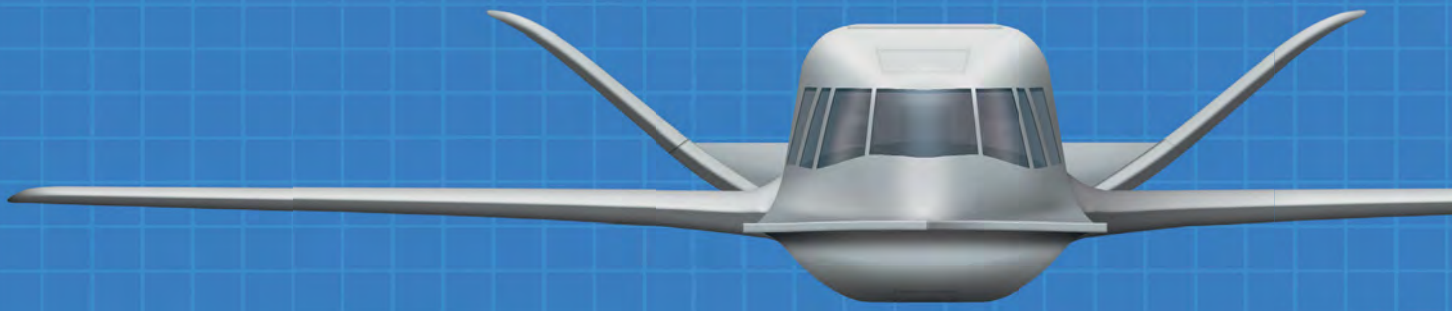
The Whale, as it was nicknamed, flew for three years. Its final 135th flight took place on February 14, 1985, so ending the programme after 250 hours' flying time. In addition to Thomas, who flew 70 of the flights, four USAF pilots participated in the classified flight tests: Maj Daniel R Vanderhor, Lt Col Donald Cornell, Lt Col Norman Dyson and Lt Col John Easter.

At the end of the programme there was no forthcoming production order for Tacit Blue, simply because its mission could be better performed by the more conventional Joint Surveillance Target Attack Radar System (Joint STARS) E-8A. This platform has a 29ft (9m) antenna and superior depth of view and could perform many of Tacit Blue's functions automatously. Adding to the lack of a production variant of Tacit Blue was that the cost of the Joint STARS programme was cheaper, the E-8A had a longer loiter time, was capable of being air-refuelled and could scan a wider area.

But what Tacit Blue brought to the fore was summed-up by Gen George Muellner, who was CO of the Air Force's secretive 6513th Test Squadron: "Tacit Blue turned into a test-bed because its low-observable technologies proved to be far more valuable than its [mission] contribution. Gaussian stealth will be one of the most important breakthroughs in defence technology over the next few decades."

It is now known that, at the time, Gen Muellner would have already been briefed about other highly classified ongoing stealth programmes such as the B-2, RQ-170 Sentinel and, allegedly the TR-3A 'Black Manta'. Northrop's 'killer whale' would revolutionise how stealth aircraft would be built for decades to come.

3



NORTHROP TACIT BLUE, GROOM LAKE TEST SITE (AREA 51), NEVADA, 1982

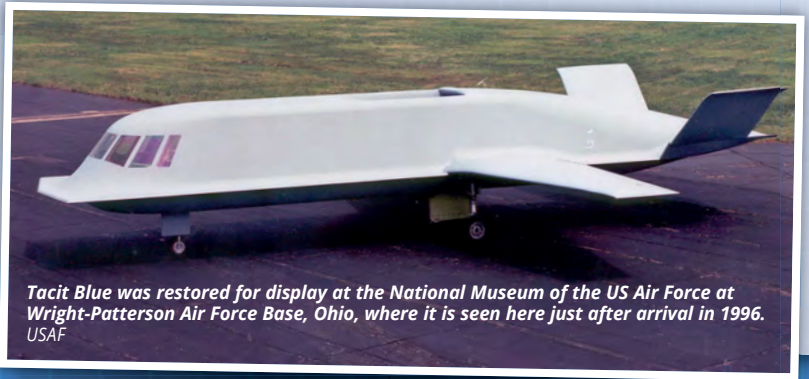
Fuselage 1: The 55ft 10in box-like fuselage was a result of having to accommodate a large phased array radar developed by Hughes, complete with all its associated software, into the airframe.
The aircraft was not fitted with standard pitot tubes on the nose and wings as these would compromise its stealth characteristics. Instead, flush-fitting differential pressure ports were blended into the leading edges of the forward fuselage and upper intake.

Fuselage 2: Tacit Blue's all-aspect stealth design philosophy has been used in nearly every low-observable US programme since, including the F/A-22 Raptor, F-35 Lightning II, the B-2A Spirit and numerous UAV programmes, including the General Atomics Predator C.

Tail Section: Heat and noise from the twin Garrett ATF-3-6 high-bypass turbofan engine exhaust was masked from the ground by the design of the flat tail section. It is believed that Northrop developed a technology (which was called 'after cooled') that was capable of chilling the exhaust heat after it had been ejected from the aircraft's engine. This, combined with chemicals that were sprayed into the exhaust, eliminated any possibility of Tacit Blue creating a contrail or being detected with heat-seeking missiles from the ground.

Cockpit: The spacious single-seat cockpit utilised many components from standard USAF fighters at the time but with the addition of a quadruple redundant digital fly-by-wire flight control system, developed from the F-16 to help stabilise the aircraft.

Wings: Spanning 48ft 2in, the wings were of an entirely conventional design with no leading-edge slats. A temporary test boom was fitted to the port wing's leading edge during the 135 test flights.

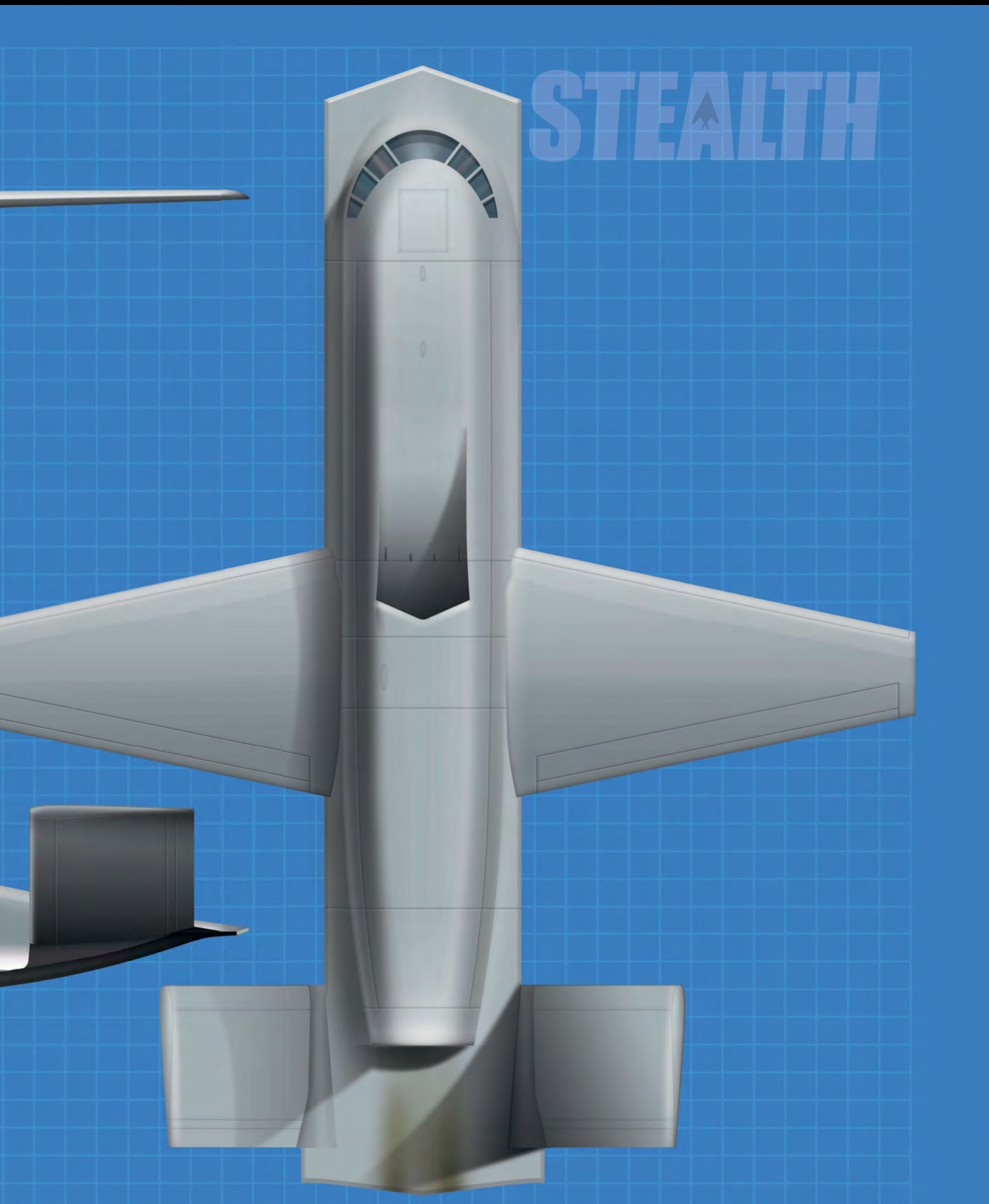


Tacit Blue was restored for display at the National Museum of the US Air Force at Wright-Patterson Air Force Base, Ohio, where it is seen here just after arrival in 1996. *USAF*

CLIENT: UNITED STATES GOVERNMENT

PROJECT: NORTHROP TACIT BLUE

Andy Hay/www.flyingart.co.uk


STEALTH

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From Russia with Stealth

T-50, Kh-101/102 and Scat – Russian Stealth Technologies

Alexander Mladenov reports on the latest Russian stealth developments, including the much-debated fifth-generation T-50 stealth fighter programme, the Kh-101 stealthy cruise missile and the Scat UCAV.

RUSSIA'S SUKHOI T-50 Perspektivnyi Aviatsionnyi Kompleks Frontovoi Aviatsii (PAK FA; Future Air Complex of Tactical Aviation) fifth-generation fighter programme continued to progress slowly through 2014 and 2015. Eight test aircraft have been involved in the protracted ground and flight trials effort. Two are ground test articles and the other six flying prototypes, used to explore the aerodynamic and system performance of the T-50's advanced design. Two or three more airworthy prototypes are expected to join the fleet before the end of 2016, with another three due to follow in 2017.

Immense design effort

The first prototype, designated T-50-1, completed its maiden flight at Komsomolsk-on-Amur on January 29, 2010 in the capable hands of Sukhoi's chief test pilot Sergey Bogdan. The second prototype, T-50-2 took the air for the first time on March 3, 2011, again with Bogdan at the controls.

The largest and most complex development effort yet undertaken by the post-Soviet Russian aerospace industry, PAK-FA incorporates several cutting-edge technologies across the areas of stealth, aerodynamics, powerplant, system integration and weapons. So far the programme has generated more questions than answers, however, and it is difficult to know how successfully Sukhoi's designers have solved the plethora of challenges posed by creating an all-new multi-role stealth design with high agility, supersonic cruise (supercruise) capability, advanced sensors and sensor fusion.

In addition to its primary air superiority role, the T-50 is reportedly capable, thanks to its stealth characteristics, of deep penetration missions against well-defended, high-value ground targets. It is considered a direct counter to the F-22 Raptor and F-35 Lightning II.

Pressure, apparently applied by Russia's President Vladimir Putin, to field the T-50 in 2015 or 2016, has failed to have the

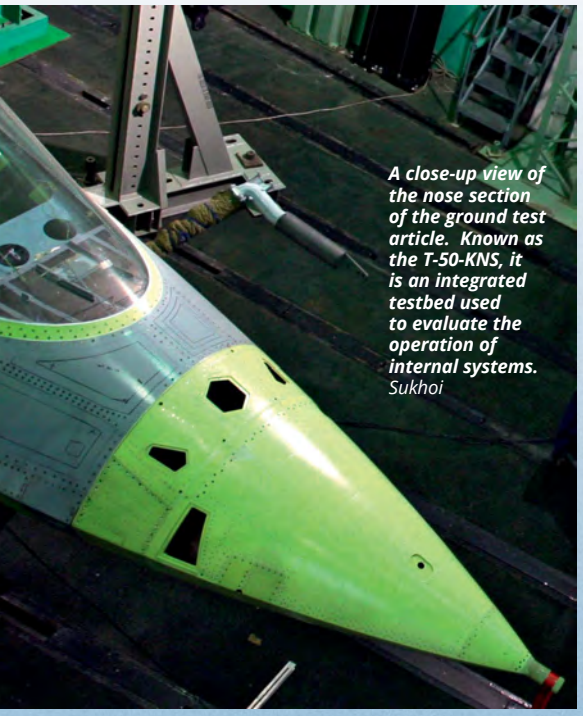
intended effect on Russia's traditionally slow defence procurement system. It is therefore realistic to predict that the aircraft will not be fielded for Russian Air and Space Force (RuASF) experimental operations and initial instructor training before 2020, with initial operating capability by 2022 at the earliest.

Frontal-aspect stealth

Sukhoi designers claim the T-50's definitive radar cross section (RCS) is 30 times smaller than that of the Su-27. Its distinctly angular, flattened fuselage shape contributes to RCS reduction, as will the extensive use of radar-absorbing coatings that is expected (although has not yet been seen on a prototype) and the aircraft's internally housed weapons.

To meet the low RCS requirement the leading edges of the wings, tailplanes and forward leading-edge extensions are parallel. The overall shape, however, suggests the T-50 has been designed to be stealthy in the forward hemisphere only, since this would grant tactical advantages in head-on encounters. There is no evidence of stealthy design in the rear hemisphere, with no effort to reduce the seemingly large RCS of the exposed engine exhaust sections and nozzles. It is also noteworthy that the engine fronts are not fully obscured by S-shaped inlet ducts, commonly used in the intakes of stealthy aircraft; their curvature is deemed insufficient to completely mask the

***Top:** The T-50's primary role is air superiority although it is also now being promoted as a deep penetration strike fighter due to its stealth characteristics. It is intended to be able to attack well-defended high-value targets well behind the front lines.* *Vlad Perminov*
***Above:** The first PAK-FA programme prototype, T-50-1, performed its maiden flight on January 29, 2010, with Sukhoi chief test pilot Sergey Bogdan at the controls. Despite appearances, it hasn't been painted – the components were made from composite materials coated with a yellow sealant.* *Sukhoi*



A close-up view of the nose section of the ground test article. Known as the T-50-KNS, it is an integrated testbed used to evaluate the operation of internal systems. *Sukhoi*

Above: The RVV-MD is a vastly improved derivative of the R-73 and is the only close-in air-to-air missile to be carried by the T-50. Below: The active radar-guided RVV-SD has a maximum range of 59nm (110km) when launched against high-altitude targets. It is the T-50's principal beyond visual range air-to-air missile. *All images by author unless stated*

engine compressors from incoming radar waves. Further masking could be achieved by the addition of radar blockers, but this aspect of the T-50 design is classified.

Super manoeuvrability

The T-50 is of blended-body aerodynamic configuration, featuring a lift-generating body, fuselage extensions for improved aerodynamic performance at high angles of attack, and high-lift leading-edge flaps on the wings. The all-moving fins and tailplanes can be deflected together or differentially. The fins, rotated in opposition, act as speed brakes.

In addition, the nozzles of the widely separated engines can be deflected in two dimensions, providing effective 3D thrust vectoring, with control exercised in the pitch, roll and yaw axes. It enables accurate control at slow speeds, when aerodynamic control becomes ineffective.

Supercruise

Supercruise capability is a must for a fifth-generation fighter. It can be achieved through the combination of two principal design features. The first calls for the reduction of drag as much as possible, since the aircraft needs a high lift-to-drag ratio at supersonic speed. The second requires a thrust-to-weight ratio exceeding 1.0 without afterburner.

Drag is considerably reduced by carrying weapons in internal bays. The wide engine installation enables the accommodation of large, deep bays in the same plane as the engines. A high thrust-to-weight ratio can be achieved through the new-generation engines in combination with a light airframe employing a vastly increased proportion of composite materials in its primary structure compared with earlier Russian/Soviet designs.

Developed by NPO Saturn-Lulka (a subsidiary of United Engine Corp), Izdelye 117 (Product 117), often referred to as a 'generation 4++' engine, is the so-called Phase 1 powerplant for the T-50 prototypes. Based on the Izdelye 117S engine used in the Su-35, it is rated at 20,938lb (93kN) dry and 33,060lb (147kN) in full afterburner.

The definitive PAK-FA engine, Izdelye 30, should be ready for flight test in 2017. The so-called Phase 2 T-50 engine, it is expected to be rated at 24,220lb (107kN) dry and 39,670lb (176.6kN) in full afterburner. Featuring a new-generation full-authority digital control, it is scheduled for initial T-50 flight trials in 2018 at the earliest.

The T-50 has variable-area intakes to optimise operating conditions in supersonic and subsonic flight, up to Mach 2.0 or even beyond. It is also assumed that the intake ducts deploy mesh grids when the aircraft is on the ground to prevent foreign object damage.

AESA and IR

The T-50 is equipped with the new NIIP Tikhomirov N036 radar. Also known as Sh121, it comprises three modules. Most important is the X-band (working in the centimetric wavelength) active electronically scanned array (AESA) in the aircraft's nose. The forward-looking primary antenna is augmented by the second module, also working in the X-band, which employs two side-looking antennas, installed just aft of the nose antenna to expand angular coverage.

The definitive T-50 radar system will include another module featuring a pair of L-band

Right: The T-50 design is optimised for low observability performance in the frontal aspect only. This is the first prototype, T-50-1, seen during its initial flight tests at Komsomolsk-on-Amur. *Sukhoi*

The blended-fuselage aerodynamic configuration features a lift-generating body with movable fuselage extensions to improve aerodynamic performance during high angle-of-attack flight. *Sukhoi*

phased-array antennas built into the leading-edge extensions. These are intended to provide enhanced detection capability against stealth aircraft, as well as for identification friend or foe (IFF). In principle, the stealth technologies fielded by Western aircraft are mostly tailored to counter airborne and ground-based X-band radars; stealth is therefore deemed less effective against L-band, decametric-wavelength radars.

The T-50's infrared search-and-track (IRST) suite includes the 101KS-V system installed in the aircraft's nose. There are also 101KS-U ultraviolet warning sensors installed under the nose and built in to the rear fuselage, plus a 101KS-O electro-optical jammer. A navigation/targeting pod is also under development.

Weapons

The T-50's centreline weapons bays are known to be capable of housing up to four K-77M (RVV-AE) medium-range active radar-guided missiles for beyond visual range engagements, with two short-range K-74M2 (RVV-MD) weapons in the side bays formed by the underwing fairings. The forward main bay can also accept air-to-surface or anti-ship missiles, or guided bombs weighing up to 350kg (550lb).

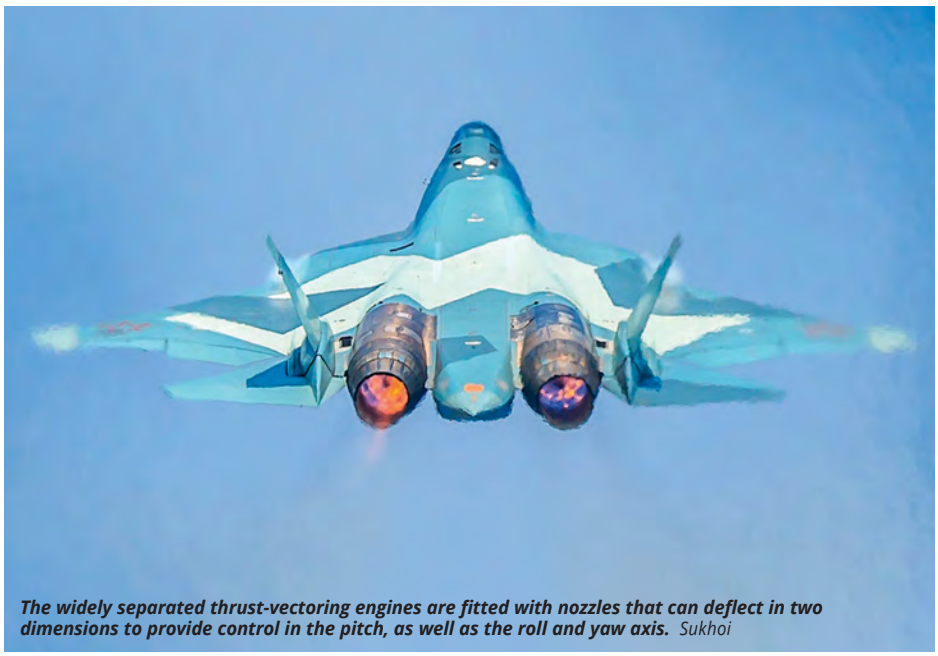
In addition, when stealth is not required the T-50 can carry missiles and bombs on four underwing pylons and two more under the engine intake trunks. In March and April 2016, the second T-50 prototype flew aerodynamic trials with six OFAB-250-270 free-fall fragmentation/high-explosive bombs.

The T-50 uses an improved version of the 30mm GSh-30-1 cannon used in the Su-27/35 and MiG-29. It is installed to starboard, with the barrel protruding adjacent to the cockpit.

In 2012, Boris Obnosov, head of the Tactical Missile Corporation (KTRV), told the Russian news agency RIA Novosti that a series of air-to-surface missiles optimised for internal carriage with folding wings, including the Kh-35UE (AS-20 *Kayak*), Kh-38ME and Kh-58UShKE (AS-11 *Kilter*), would be ready for service with the T-50 in 2014.

Test progress

According to a Sukhoi press release distributed in early March 2011, preliminary ground and flight trials had been completed using the two ground tests articles and



The widely separated thrust-vectoring engines are fitted with nozzles that can deflect in two dimensions to provide control in the pitch, as well as the roll and yaw axis. *Sukhoi*

The T-50-4 is the PAK-FA programme's fourth flying prototype – it took to the air for the first time in December 2012. It is currently in service with RuASF's Flight Test Centre at Akhtubinsk performing trials work. *Vlad Perminov*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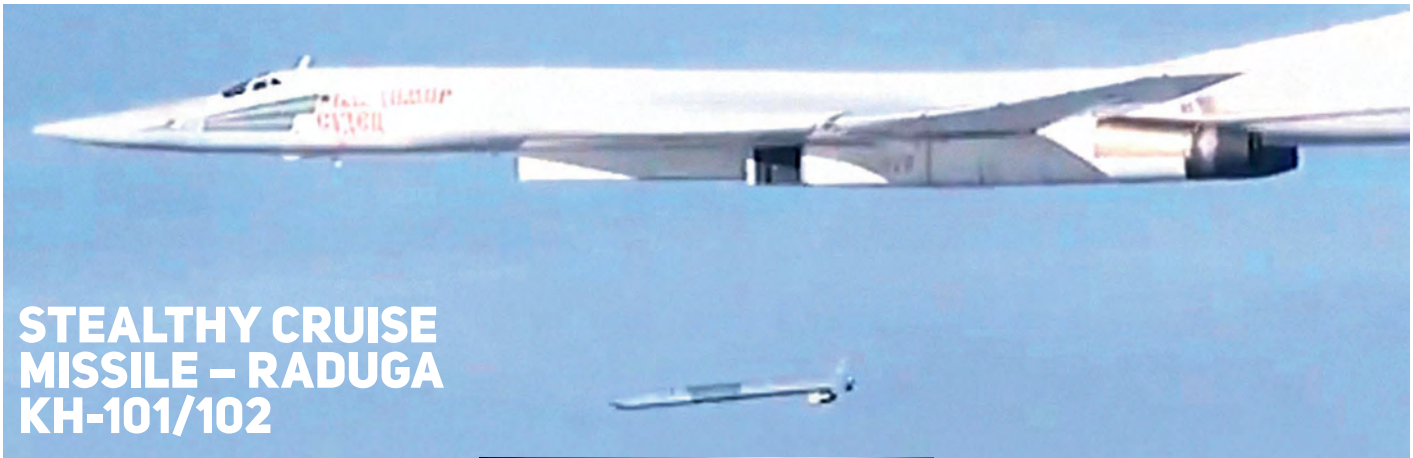


STEALTHY CRUISE MISSILE – RADUGA KH-101/102

RUSSIA'S ONLY known stealthy air-launched missile, the Raduga Kh-101/102 family of new-generation air-launched cruise missiles (ALCMs) was designed for the upgraded Tu-160 and Tu-95M strategic bombers. Generally based on the smaller and non-stealthy Kh-55, they are much larger and heavier, with a considerably reduced RCS.

The Kh-101/102, the only successful Russian stealth project to date, is in large-scale production. Russian sources note that the weapons' RCS is significantly reduced through shaping and the use of composite materials that absorb electromagnetic energy.

The Kh-101 has an 882lb (400kg) conventional warhead, while the Kh-102 has a nuclear warhead of 250kT yield. The missiles weigh 5,400lb (2,500kg) and are powered by a retractable turbofan. The nuclear version has a range of 2,967nm (5,500km), while the Kh-101 has a shorter reach due to its heavier warhead. The weapons reach up to 970km/h at altitudes between 100 and 19,680ft. Guidance is by terrain-contour matching (TERCOM), enhanced with INS/satellite en-route correction (using a combined GLONASS/GPS receiver). Terminal phase guidance switches to TV scene matching. This combined guidance method achieves high accuracy, with a claimed circular error probable of between 40 and 66ft (12 and 20m).

The Kh-101/102 was developed under a classified programme and few hard facts are known. It was tested for the first time in 2004 and reportedly commissioned into RuASF service in 2013. The Kh-101/102 can be carried internally only by the upgraded Tu-160 *Blackjack*; its two new rotary launchers can accommodate up to 12 missiles between them. The Kh-101/102 is too large for internal carriage by the Tu-95MS *Bear-H*, but as many as eight can be suspended from external pylons on four twin-round launcher units.

The Kh-101 saw its combat debut on November 17, 2015 as Tu-160s launched it against anti-Assad forces in Syria. Conducted on President Vladimir Putin's orders, the operation marked decisive retaliation for the terrorist action that brought down a MetroJet Airbus A321 over the Sinai Peninsula on October 31, 2015.

***Main image:** A combat launch of an Kh-101 during the Russian military campaign in Syria. More than 48 missiles were fired in four days at the start of the air campaign by the upgraded Tu-160 strategic bombers.* Russian MoD ***Above:** A Kh-101 missile is loaded into a Tu-160's forward weapons bay.* Russian MoD ***Above right:** A close-up view to the Kh-101's flattened nose, purposely designed for stealth.* Russian MoD

T-50-1, the lone flight test prototype, which had amassed 36 sorties. Work comprised evaluation of stability and controllability, and other characteristics, during an expansion of speed, altitude and *g* limits. The aircraft exceeded the speed of sound for the first time on March 9, 2011.

The third flying prototype, T-50-3, flew for the first time on November 22, 2011 at Komosomolsk-on-Amur. After initial test flights it was transported by air to Sukhoi's main test base at Zhukovsky, near Moscow, on December 28. Here it continued system testing and evaluation as the first T-50 fitted with the Tikhomirov Scientific Research Institute of Instrument Design N06 AESA radar. It also features a pair of 101KS-U sensors under its nose and on the tail boom, and three UV-50 chaff/flare dispensers in the rear fuselage.

The fourth flying prototype, T-50-4, took to the air in December 2012, T-50-5 then followed in October 2013. Both aircraft are dedicated to avionics and sensor trials, featuring many integrated avionics suite components lacking on the T-50-1 and T-50-2.

Sukhoi's former head, Mikhail Pogosyan

A trio of T-50 prototypes (-1, -2 and -4) fly in formation during a display at the MAKS airshow in August 2013.

hinted to the aviation media that the primary flight test aims in 2010 and 2011 were to achieve so-called preliminary approval from RuASF authorities. This is an important initial programme milestone, confirming that the aircraft has performed as expected and the test effort can proceed into the next phase. This is so-called joint state-testing, undertaken by Sukhoi and the Russian defence ministry, with the 929th State Flight Test Centre at Akhtubinsk.

The test programme has encountered major technical issues, the most serious affecting T-50-5, which sustained extensive damage in a fire immediately after landing at Zhukovsky on June 10, 2014. It was rebuilt with the new designation T-50-5R, using the fuselage built for T-50-6, mated to the wings and surviving systems of the T-50-5. It took to the air for the first time in its new guise in October 2015. T-50-6 was completed with new components, but significantly delayed; it had not flown by the end of July 2016.

Three prototypes, T-50-2, T-50-3 and T-50-4, are known to have been handed over to the 929th GLITs. They fly radar and weapons testing, with the carriage of dummy missiles in their internal bays and on external pylons, out of Akhtubinsk and Zhukovsky. As of early 2016, no live missile testing was known to have been carried out.

Delayed development

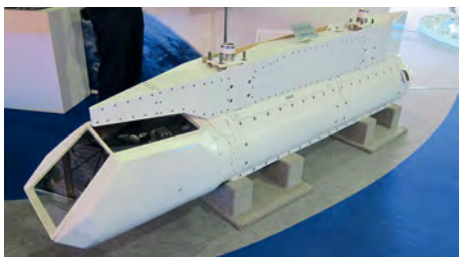
In early 2015, official Russian sources admitted the T-50 has suffered protracted development and completion of test and evaluation efforts is expected at the end of decade at the earliest.

The RuASF had hoped to have as many as 13 aircraft involved in test and evaluation by 2013, with the initial production-standard fifth-generation fighters delivered in 2015. In fact, only five T-50 prototypes were available by early 2016. Four more are slated to join the fleet before the end of the year, while the first production T-50, intended for field trials (experimental operations conducted by a squadron-sized RuASF unit) should be delivered in 2017.

High-ranking Russian defence ministry representatives, including the deputy defence minister responsible for procurement, Yury Borisov, claimed in public during early 2015 that PAK-FA testing has encountered further technical problems. As a consequence, the number of production-standard aircraft to be ordered under Russia's State Armaments Programme 2020 will reduce from 52 to 12. This figure is deemed sufficient to equip one squadron for field trials. At a later stage the defence ministry will decide how many aircraft are required overall and how many the service can actually afford.

The sharp cuts in the initial procurement plan most likely resulted in part from the unsatisfactory performance of the five prototypes tested between 2010 and 2015, all powered by the first-stage Izdeliye 117 engine. The far more powerful second-stage Izdelye 30 remains under development and is not expected to be ready for production T-50s until 2020 at the earliest. In addition, T-50-1 was subject to a good many structural modifications in an effort to strengthen its fuselage after initial test results revealed failures under flight loads.

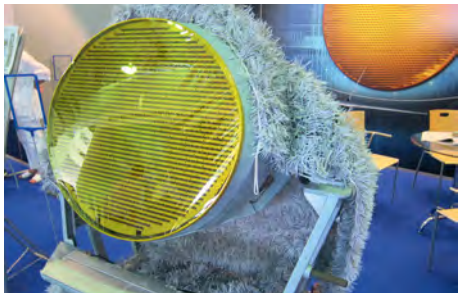
By late 2015, the five T-50 prototypes had exceeded 700 flights.



***Above:** The KAB-250 and Kh-58UShKE(IR) are two new-generation guided air-to-ground munitions intended for the T-50. The KAB-250, in the foreground, is a GLONASS/INS-guided bomb, while the Kh-58UShKE(IR) is an anti-radar missile with terminal infrared guidance.*
***Left:** The 101KS-N is a targeting and navigation pod developed for the T-50 by the UOMZ company.*

Indian derivative

The PAK-FA programme is also the basis for development of an international derivative. The work will be undertaken with India after an intergovernmental agreement was



***Above:** A view of the T-50 cockpit demonstrator, showing the two large colour multi-function displays and wide-angle head-up display.* Sukhoi
***Above right:** The Zvezda K-36D-5 is the new-generation ejection seat for use on the T-50.*
***Right:** The antenna of the N036 AESA X-band radar installed in the T-50's nose is tilted upwards by 15°.*

formalised in 2007. A subsequent tripartite contract signed in December 2010 by Sukhoi, Hindustan Aeronautics Limited (HAL) and Russia's Rosoboronexport, covered the preliminary development effort for what the Indians term the Fifth Generation Fighter Aircraft (FGFA). Valued at $295m, the contract was set to run for 18 months.

Sergey Bogdan claims that during FGFA negotiations the Indians expressed their requirement for participation in aircraft testing and the development of systems, in an effort to raise their level of technological competence.

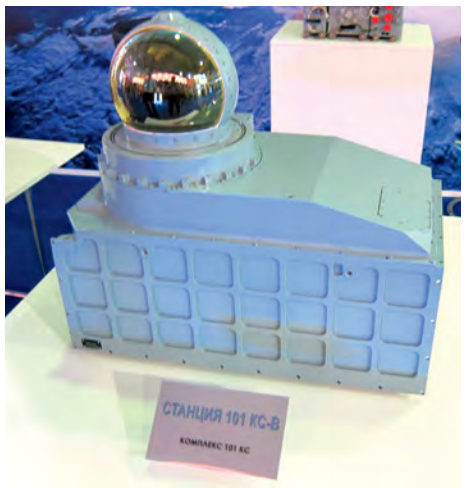
According to Indian defence ministry information released at the time, the FGFA will be a two-seater powered by higher-thrust engines than the PAK-FA, in an effort to meet very demanding Indian Air Force (IAF) requirements. It was expected, subject to the development and production efforts advancing as planned, that between 250 and 300 aircraft would be ordered; Sukhoi sources note a potential programme value of $25bn.

Such numbers would create the largest ever Indian military programme. In addition to production for domestic use, the intergovernmental agreement enables marketing and sales of the FGFA to other countries. There will be no dedicated export T-50 version – only the FGFA will be available for sale abroad. Customers are expected from within the group of rich, demanding buyers of Russian heavy multi-role fighters from the last decade. The development effort was scheduled for completion by 2016 or 2017, with induction into IAF service no earlier than 2020.

In August 2015, India's *Tribune News* newspaper hinted at a reduction of the IAF order from 127 to 65 aircraft, sufficient for three 18-aircraft squadrons. By 2014, high-ranking Indian military representatives had already expressed their dissatisfaction with the T-50's engine performance and low-observability characteristics, as well as its weapons and the project's timeframe.

Negotiations for the FGFA joint full-scale development contract are continuing. The draft contract envisages first FGFA deliveries 94 months after signature.

In February 2016 it was revealed that Russia and India had reached a general agreement on significant FGFA cost reduction during the visit of Indian Prime Minister Narendra Modi to Moscow in December 2015. It calls for both partners to invest $4bn over the next seven years. Russia's United Aircraft Corp and HAL are the nominated industrial partners, while India's Bharat Electronics will also have significant participation.



***Above:** The 101KS-V is the T-50's infrared search-and-track sensor and is installed in front of the windshield.*
***Left:** The 101KS-O is an electro-optical directional jammer.*

STEALTH UCAV

Above: In 2007, Russia publicly unveiled its first stealth unmanned combat air vehicle, the Scat, although it was only a full-scale mock-up at this stage.

THE ONLY publicly acknowledged Russian unmanned combat air vehicle (UCAV) project, Scat incorporates RCS-reduction technologies. Developed by RSK MiG, Scat was first presented in public in 2007 as a full-scale mock-up. It generated a great deal of interest, but failed to mature into a flying prototype.

Then Designer General at RSK MiG, Sergey Tsivilev claimed that Scat had been conceived as a UCAV from the outset.

Of flying wing configuration, it was to be built in composite materials. Power was expected to come from a 49.4kN (11,108lb) thrust Klimov RD-500 turbofan, while maximum take-off weight was 10,000kg (22,046lb) and maximum combat load 2,000kg (4,408lb), held in two bays. Planned maximum range was 4,000km (2,157nm) and ceiling 12,000m (39,360ft).

Work had begun in 2005, with the full-scale mock-up rolled out in 2007. The next stage foresaw construction of a flying prototype for development of the new technologies but it was never initiated, mainly due to an apparent lack of interest from the Russian defence ministry.

Above: The Scat UCAV is a single-engine subsonic design, advertised as being able to carry two tonnes of armament in two internal weapon bays. *RSK MiG*

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KEY

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The Spirit of Stealth

Tom Kaminski examines the continued service of Northrop Grumman's B-2A Spirit – and the rolling upgrades helping keep the aircraft at the top of its game.

THE 509TH Bomb Wing's (BW's) B-2A Spirit fleet has flown around 3,000 combat hours since it made its debut on the opening night of Operation Allied Force over Kosovo on March 24, 1999.

The Spirit was the first aircraft to penetrate Serbian air defences, two B-2As having launched from their home base at Whiteman AFB, Missouri. One struck pre-planned targets while the other re-targeted all 16 of its weapons in flight.

When operations ended on May 21, six B-2As had conducted 47 combat sorties from Whiteman. Each mission lasted between 28 and 32 hours, typically averaging around 31.

Spirits were responsible for less than 1% of the 34,000-plus sorties flown by US forces and delivered 656 weapons, totalling 1.3 million lb for an average of 14.6 weapons per sortie. Precision-guided weapons expended included 4,700lb GBU-37/B GPS Aided Munition (GAM) 'bunker busters' and 2,000lb GBU-32 Joint Direct Attack Munitions (JDAMs). Remarkably, this small number of B-2As was responsible for destroying 11% of the fixed targets in Serbia and Kosovo. Using the GPS Aided Targeting System (GATS) and GPS-guided weapons, the aircraft successfully struck around 80% of their assigned targets on the first pass. At a Department of Defense briefing on April 22, 1999, Maj Gen Charles Wald said one B-2A with smart bombs "could probably do more damage than 1,500 B-17s, because of precision and the ability to target the right thing".

The B-2A next saw combat following the 9/11 terror attacks on New York and Washington DC. Spirits were the first aircraft to attack Afghan targets, flying six missions in the initial days of Operation Enduring Freedom from October 6 to 11, 2001. During the 44-hour-plus missions which began at Whiteman, crews delivered a total of 64 weapons against targets in Afghanistan and recovered to the forward operating location (FOL) at Naval Support Facility Diego Garcia, British Indian Ocean Territory (BIOT).

The 7,500-mile (12,100km) flights from Whiteman to Afghanistan called for six in-flight refuellings. Engine running crew changes (ERCCs) were conducted during several missions, a second crew flying the 29-hour return flight to Whiteman.

The bomber's longest missions, lasting 73.3 hours and including two sorties, all involved ERCCs. The longest single-crew mission lasted 44.3 hours.

Iraq and Libya

The B-2 flew its first Operation Iraqi Freedom missions from Whiteman on March 21, 2003. Nine aircraft flew sorties from the base, while the bomber's first combat deployment saw four B-2As operating out from Diego Garcia, the first time dual basing was used.

By April 8 the bombers had delivered 676 JDAMs, GBU-37 GAMs and 500lb unguided bombs, totalling 1.5 million lb, against some 600 individual targets in 41 missions. They eventually flew 27 sorties from Whiteman and 22 from the FOL ➤

***Left:** A B-2 pilot accompanied by an airman walks towards the bomber for an engine-running crew swap during Exercise Polar Lightning in March. The B-2As were deployed to Andersen AFB, Guam in the Pacific region for the exercise.* *All images USAF unless stated*

Above: Serving as part of the 40th Air Expeditionary Wing, B-2s flew alongside B-52s during Operation Iraqi Freedom. The Spirits were selected to attack Iraq's most heavily defended targets.

On March 21, 2011, following attacks by more than 110 Tomahawk cruise missiles, three B-2As delivered 45 GPS-guided weapons which destroyed hardened aircraft shelters on Ghardabiya air base near Sirte, Libya. The sortie was conducted in support of the United Nations' no-fly zone over Libya at the beginning of Operation Odyssey Dawn.

Each of the 25-hour-plus, 11,418-mile (18,375km) round trip missions originated at Whiteman.

Reduced deliveries

Selected to build the US Air Force's new Advanced Technology Bomber (ATB) in October 1981, Northrop originally received a contract to build two structural test B-2A airframes, one flying prototype and five evaluation aircraft.

Plans then called for the five test aircraft to be refurbished and enter operational service once testing was complete. Northrop eventually delivered operational B-2As in three different Block configurations – Block 10, 20 and 30 – each delivering new capabilities.

The USAF's production plans originally called for the acquisition of 132 B-2s, including the five test aircraft. Following a Department of Defense Major

Aircraft Review, however, the total was reduced to 75 in 1990; by 1992 it was down to just 20 operational aircraft.

US lawmakers eventually authorised funding for the conversion of the first test vehicle into a combat bomber, bringing deliveries to 21.

The prototype and developmental B-2As (AV-1 to 6) were followed by ten of the Block 10 model (AV-7 to 16), which had only limited combat capability. Delivered between December 1993 and January 1996, the Block 10 was certified to operate at a maximum take-off weight of 305,000lb (138,346kg). Its weapon capabilities were limited to the 2,400lb variable-yield B83 nuclear bomb and 2,000lb Mk 84 conventional general-purpose (GP) bomb.

Three Block 20 production aircraft followed (AV-17 to 19), capable of operating at an increased maximum take-off weight of 336,500lb (152,634kg) and featuring a limited terrain following/terrain avoidance (TF/TA) capability for operations as low as 600ft.

They also featured an upgraded environmental control system and their Lockheed Martin AN/APR-50 Defense Management Subsystem (DMS) provided limited capability.

New weapons added to the Block 20 included the 700lb variable-yield B61 nuclear bomb; and conventional cluster bomb units, including the 1,000lb CBU-87 Combined Effects Munition, CBU-89 Gator and CBU-97 Sensor Fuzed Weapons.

Additionally, the Block 20's GATS enabled it to deliver precision-guided 2,000lb GBU-36/B and 4,700lb GBU-37/B GAMs. Each aircraft could carry 16 GBU-36s or eight of the larger weapons.

Developed specifically for the B-2A and produced in limited numbers, the GAM was later replaced by JDAM. The GATS worked in conjunction with the Raytheon AN/APQ-181's synthetic aperture radar mode and a GPS receiver to determine target co-ordinates for the GAM.

After delivery of the first Block 20 (AV-18) to the 509th BW on May 15, 1996, it achieved initial operating capability (IOC) for conventional missions on January 1, 1997 and for nuclear work on April 1.

As well as the three production Block 20 aircraft, Northrop upgraded five Block 10s (AV-12 to 16) to the ➔

Above: The B-2A Spirit has received a steady stream of upgrades ensuring the bomber is kept at the forefront of available technology to help counter the various global threats now facing Western nations. Below: This photograph illustrates the rudderons on the B-2's wingtips. The complex arrangement of control surfaces is essential for keeping this intrinsically unstable aircraft airborne. The bomber's flight control computers and fly-by-wire systems manage the associated workload.

configuration from 1996. The final Block 20 delivery took place in May 1997.

Structural modifications, radar cross-section (RCS) and radar absorbent material (RAM) coating improvements all featured on the Block 30. There was also a partial rewiring, full JDAM integration and incorporation of bomb rack assembly units for the B-2A to carry additional munitions, including 500lb Mk 62 aerial mines, 750lb Mk 117 GP bombs and other smaller stores.

Additionally, a Milstar satellite communications terminal was incorporated and the DMS achieved full capability. Radar enhancements included a ground moving-target indication (GMTI) mode and enhanced TF/TA capabilities facilitating flight as low as 200ft.

The first of two production Block 30s (AV-20) flew at Palmdale's Air Force Plant 42 on April 15, 1997 and arrived at Whiteman on August 7, 1997. Block 30 upgrades began at Palmdale in July 1995 and the final aircraft was delivered in July 2000, when conversion of the prototype (AV-1) was completed.

Six development aircraft, five Block 10s and eight Block 20s were converted to Block 30 configuration.

The USAF announced full operating capability for the B-2 force on December 17, 2003. Today, although the entire fleet of 20 surviving bombers is currently fielded in Block 30 configuration, the B-2A is continually upgraded as the USAF's only long-range, penetrating anti-access/area denial (A2/AD) platform.

The initial block and individual upgrades improved the bomber's stealth characteristics, expanded its weapons employment options and improved offensive and defensive avionics. Follow-on projects continue to provide additional capabilities.

Radar modernisation

The AN/APQ-181 multi-mode radar was updated as part of the B-2 Radar Modernization Program (RMP), which began in 2002. It replaced the system's passive electronically scanned antennas with a Ku-band active electronically scanned array (AESA) antenna and modified radar receiver/exciter.

***Above:** Illuminated only by the lights on the KC-135R's boom, a B-2 tops off its tanks before heading into enemy airspace for another strike during Operation Iraqi Freedom.*

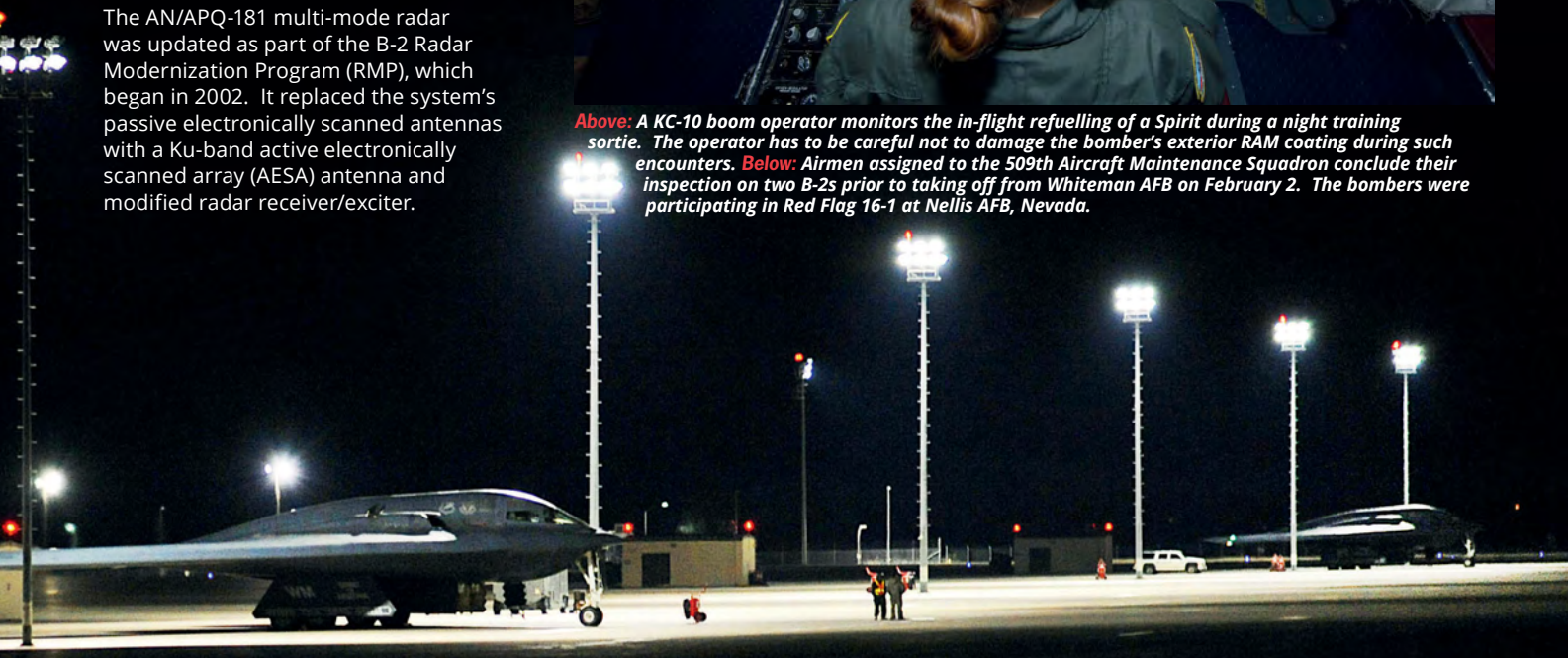
The RMP resolved potential conflicts in radio frequency usage between the bomber and commercial satellite systems operating in the same frequency spectrum. Northrop Grumman received a $382m RMP system development and demonstration (SDD) contract in 2004, providing for the modification of seven B-2As.

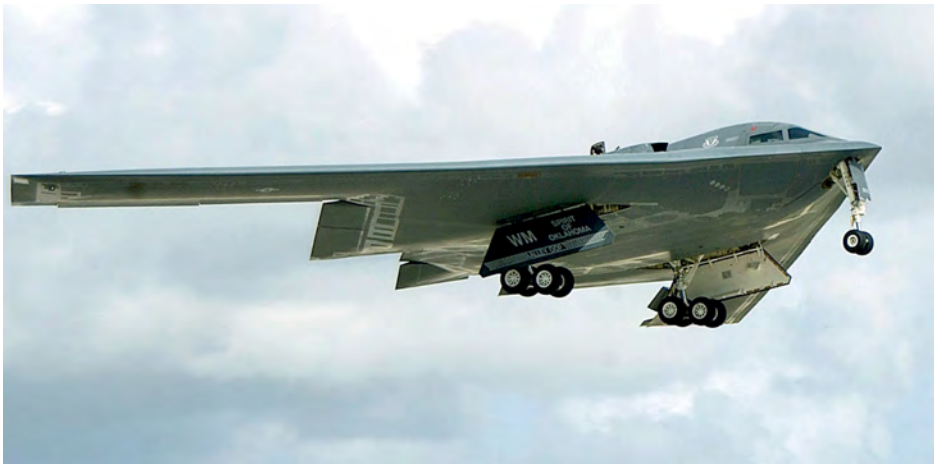
Flight trials with the new radar began aboard AV-3 in April 2006 after the B-2 Combined Test Force (CTF) had completed initial radar subsystem integration and acceptance testing.

The first aircraft equipped with the modified radar as part of the RMP SDD phase was turned over to the USAF on March 17, 2009. Radar installation in the last of five SDD aircraft was completed at Whiteman in November 2009.

Low rate initial production (LRIP) began in November 2008 and full rate production (FRP) in November 2009. The first LRIP installs began in July 2010. The remainder of the fleet received the modifications under a

***Above:** A KC-10 boom operator monitors the in-flight refuelling of a Spirit during a night training sortie. The operator has to be careful not to damage the bomber's exterior RAM coating during such encounters. **Below:** Airmen assigned to the 509th Aircraft Maintenance Squadron conclude their inspection on two B-2s prior to taking off from Whiteman AFB on February 2. The bombers were participating in Red Flag 16-1 at Nellis AFB, Nevada.*





***Above:** Despite the seemingly uniform finish of the aircraft's skin, this view of Spirit of Oklahoma illustrates the varied discoloured appearance of the bomber where its RAM has been repaired and upgrades installed on the fuselage.*

$468m contract issued in December 2008.

Northrop Grumman delivered the last of 13 production installations in September 2012, having performed them at Whiteman and Palmdale.

Maintenance and modification

Depot-level B-2A maintenance and major modifications are managed by the Oklahoma City Air Logistics Complex at Tinker AFB, Oklahoma, but typically carried by Northrop Grumman at its Aircraft Integration Center of Excellence at the Air Force Plant 42 Production Flight Test Installation in Palmdale, California. The work is often carried out while the aircraft undergo programmed depot maintenance (PDM).

Until recently, each B-2A was subject to PDM at Palmdale every seven years, but the overhaul cycle is being extended to nine years in an effort to increase the bomber's availability.

It also reduces the average PDM time from more than 400 days to 365 days, resulting in the addition of an equivalent operational aircraft to the fleet; over the type's service life it will also save around $900m in maintenance costs.

Northrop Grumman provides Spirit support and modernisation under the terms of a five-year indefinite delivery/ indefinite quantity Flexible Acquisition Sustainment Team (FAST) contract awarded in June 2014. Worth up to $9.9 billion, it includes contract depot maintenance (CDM), consolidated delivery orders (CDOs) and integrated contractor support (ICS).

While PDM and most major modification projects are conducted at Palmdale, smaller tasks are carried out at Whiteman. A number of ongoing projects are being conducted under FAST and other contracts.

SATCOM upgrades

Upgrades associated with the B-2 Extremely High Frequency Satellite Communications (EHF SATCOM) Increment 1 (B-2 EHF Inc 1) programme were carried out at Palmdale and Whiteman.

The EHF SATCOM system replaced the Spirit's ultra-high frequency (UHF) communications equipment and provides compatibility with the legacy EHF Satellite (MILSTAR I/II) and future Advanced Extremely High ➤

***Above:** This view of a B-2 shows the airflow baffles that drop down in front of the weapons bays to ensure clean separation of bombs.*

MOP

INTEGRATION OF the 29,000lb GPS-guided GBU-57 Massive Ordnance Penetrator (MOP) gave the B-2A the ability to attack hardened, deeply buried targets.

The 20ft-long (6.1m) weapon can reportedly penetrate as much as 200ft (61m) of reinforced concrete before exploding. Integration began in July 2007 and the B-2 remains the only aircraft capable of carrying the weapon.

The MOP modification work also included an upgrade to the Global Positioning System antenna, enabling the weapons bus to transmit enhanced GPS signals to weapons carried on the bomber's Monitor and Control Equipment (MACE), Smart Bomb Rack Assembly (SBRA) and Rotary Launch Assembly (RLA) to acquire and track GPS satellites prior to release.

The subsequent integration of the Link-16/Center Instrument Display/In-Flight Replanner (CID/IFR) gave aircrew access to theatre tactical data links, which provided improved situational awareness and greatly enhanced the ability of theatre commanders to co-ordinate the B-2 with other assets.

The project included installation of a CID digital video recorder that stores video from the display for mission playback, operational assessment and debriefs to be conducted post-flight and in support of aircrew training.

***Above:** The USAF took delivery of 20 GBU-57 MOPs in September 2011 that are specifically designed for the B-2. An improved MOP is now in development.* Northrop Grumman

Frequency (AEHF) SATCOM systems.

The project provides the bomber with a new integrated processing unit (IPU), upgraded flight management computer processors, increased data storage, a re-hosted flight management operational flight programme and a high-bandwidth data bus that supports the EHF SATCOM installation and provides growth potential for future upgrades. In addition, a fibre-optic cable network will support high-speed data transfer.

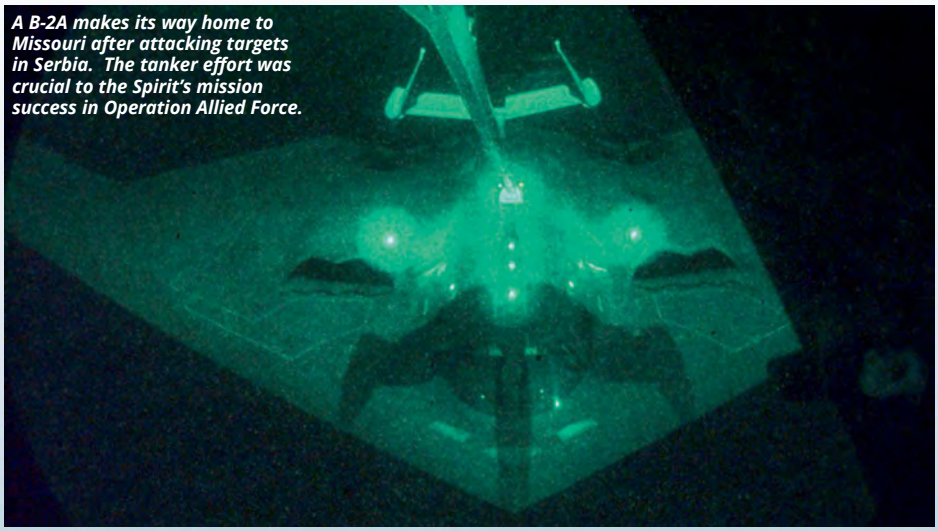
Prototype hardware installation began at Edwards AFB in early 2010 and four developmental installations were carried out. Flight test began there on September 1 and initial operational test and evaluation (IOT&E) was conducted between June and August 2012.

Following the award of a $108m contract on September 28, 2012, Northrop Grumman began LRIP on five systems. They were certified as compatible for conventional operations on April 2, 2013 and Air Force Global Strike Command (AFGSC) authorised fielding and use of EHF-modified aircraft for conventional and nuclear missions on April 26, 2013.

The first production installation began in November 2013 and FRP of the final 11 systems was approved in July 2014.

A new communications terminal and AESA antenna – enabling the B-2 to transmit and receive battlefield information securely by satellite up to 100 times faster – was included in a proposed EHF Increment 2 effort.

Increment 3 would have subsequently integrated the B-2 into the Department of Defense's Global Information Grid and provide Net Ready capability.



A B-2A makes its way home to Missouri after attacking targets in Serbia. The tanker effort was crucial to the Spirit's mission success in Operation Allied Force.

Development of the new antenna began in 2011 under a $372m contract.

Increment 2 was, however, terminated in December 2013 and Increment 3 cancelled. Both have been replaced by the Advanced Extremely High Frequency Satellite Communications (AEHF SATCOM).

Flexible Strike

Northrop Grumman began work on the three-year engineering and manufacturing development (EMD) portion of the Flexible Strike Phase 1 programme when it received a $102m contract in August 2014. A critical design review (CDR) was completed the following February and approval granted to move ahead with the development and integration of new software and hardware.

Previously known as the Stores Management Operational Flight Program (SMOFP) re-host and mixed carriage modification, it will provide the B-2 with an expanded processing capability, re-hosting the SMOFP software into the IPU added under EHF Inc 1.

An associated software upgrade will serve as the basis for future system enhancements, including the ability to simultaneously carry multiple weapon types and integrate with the advanced digital interfaces used with newer weapons, including the upgraded B61-12 nuclear bomb.

It will also reduce maintenance costs and improve mission flexibility and aircraft reliability, while a single operational flight programme (OFP) will replace several mission-specific software versions.

Phase 2 will facilitate mixed weapon loads, including an RLA in one bay and an SBRA in the other. This will enable simultaneous carriage of a GBU-57 MOP and 2,000lb or 5,000lb penetrator weapons. It will

The B-2A's shape was purposely designed to minimise its presence in the visual, audio and electronic spectrums. From a distance, the Spirit appears almost wafer-thin in silhouette.

also provide for full integration of B61-12 Life Extension Program (LEP) upgrades.

The mixed loads capability will greatly improve the aircraft's strategic nuclear and conventional strike capability. In August 2014 EMD began and four aircraft have been modified. Production is expected to get under way in 2017 and the remaining 16 aircraft will be upgraded between mid-2018 and mid-2020.

Intended to resolve the B-2's Diminishing Manufacturing Sources and Material Shortages (DMSMS) and improve sustainability, the Defensive Management System Modernization (DMS-M) is the number one priority modification for the B-2 fleet. Expected to cost around $310.9m, it will upgrade the electronic support measures, passive antennas and display processing units that make up the bomber's electronic warfare system.

***Left:** Stealth bombers have been frequent visitors to the UK, normally in twos or threes for global training missions and short-duration deployments. On these occasions they operate out of RAF Fairford in Gloucestershire.* AirTeamImages.com/ Adrian Jack

The modification enhances the aircraft's direct attack capability and enables it to penetrate dense threat environments via improved threat location and identification capabilities and real-time re-routing; it also improves survivability against advanced integrated air defence systems.

Initial DMS-M flight test is planned for 2017 and the programme is currently in its SDD phase.

The system includes a new avionics graphics processor developed by Lockheed Martin and antennas developed by L3 Communications and Ball Aerospace. Four kits will be procured for the EMD phase and the first installation will occur in Fiscal (Year) 2017.

Developmental test and evaluation (DT&E) is scheduled to begin in Fiscal 2018 and DMS-M is expected to enter LRIP in 2020, with FRP following in 2021.

CVR and LOSSM

Development associated with the Common Very Low Frequency Receiver (CVR) Increment 1 began in 2013. This project includes a very low bandwidth, very low frequency (VLF) receiver and antenna subsystem to achieve a secure, survivable, beyond-line-of-sight (BLOS) strategic nuclear communication capability.

It will also be capable of receiving emergency action messages (EAMs) in support of US Strategic Command's (USSTRATCOM's) nuclear command and control requirements.

The project entered EMD in 2013 and combined developmental testing/ operational testing (DT/OT) and approval for LRIP is expected later this year.

Meanwhile, the Low Observable Signature and Supportability Modifications (LOSSM) and Aircraft Supportability Modifications ➤

***Above:** Aircraft shelters at Whiteman AFB are specially designed with front and rear opening doors enabling the Spirit to start its engines prior to taxiing to the runway.* Don Logan

***Below:** Spirit of Kitty Hawk prepares to touch down on the long runway at Whiteman AFB. The nose art and markings, which are usually seen on other USAF aircraft, are absent from the B-2As. They have an altogether more sober appearance, which reflects their deadly mission.* Don Logan

(ASM) will implement a mix of more than 20 improvements designed to slow low observable signature degradation and improve low observable (LO) supportability.

The projects include structural modifications and material improvements that provide advanced signature reduction, reduce LO maintenance and improve overall survivability and aircraft availability. Specific modifications, carried out at Whiteman and Palmdale by USAF and contractor personnel, will vary from airframe to airframe.

The B-2A is also the lead platform for the Military GPS User Equipment (MGUE) initiative – which replaces the Miniature Airborne GPS Receiver (MAGR) and GPS antenna with a new M-Code GPS Receiver (MAGR-M) and a Controlled Reception Pattern Antenna (CRPA) for enhanced satellite acquisition and tracking, improved navigation accuracy and increased security.

Developmental flight test began in Fiscal 2016 and production will begin in 2017. Four aircraft are being upgraded under the research, development, test and evaluation (RDT&E) phase and 16 production installations will be carried out between mid-2018 and mid-2020.

Above: ***The B-2As were able to generate more missions and become force multipliers by flying from Diego Garcia during Operation Iraqi Freedom. The bomber and tanker crews were familiar with this location having used this tropical base following Operation Enduring Freedom in 2001.***

Future upgrades

New-start programmes beginning in 2017 include cryptographic modifications and Adaptable Communications Suite (ACS) capability improvements.

Mandated by the National Security Agency's (NSA's) Cryptographic Modernization Initiative, the former will provide modifications to the AN/ARC-234 UHF/VHF radio (Advanced Integrated Terminal), AN/ARC-211 HF radio and the Multifunction Information Distribution System (MIDS) low volume terminal (Link-16 terminal).

The ACS is a non-integrated avionics and communication system enabling the B-2 crew to receive complete integrated mission data, time sensitive targeting information and intelligence updates.

The USAF is also studying multiple structural and avionics modifications that may improve the performance of the aircraft and its engines as well as reducing maintenance and logistics requirements.

Work will potentially be done on the B-2 Common Processor, generator control unit, rudder access panel, cockpit voice and flight data recorder, radomes, audio control display unit and centre instrument display.

Numerous low-cost upgrades addressing safety, reliability, maintainability and/or improved system performance issues may also be implemented.

Additionally, low-cost engine modifications are providing the bomber's 19,000lb-thrust (84.5kN) General Electric F118-GE-100 engines with a service life extension programme at a cost of $13.8m for the fleet. As well as an extended-mission oil tank upgrade, the work provides improvements to the stage one and three fan blades, enhancing

Above: ***The AGM-158B Joint Air-to-Surface Standoff Missile Extended Range (JASSM-ER) is intended to be integrated into the B-2 fleet within the next few years under the USAF's Flexible Strike programme.*** *Lockheed Martin* ***Below:*** ***A B-2 Spirit on the flight line at Whiteman AFB, Missouri, is prepared for a night-time training sortie.***

engine reliability and performance.

The engines were equipped with a new full authority digital engine control (FADEC) under a previous modification.

Testing of new systems continues at Edwards AFB, where the B-2 CTF evaluates new systems that might be added to the aircraft. A June 2015 test, for example, demonstrated the capability to rapidly integrate new subsystems onto the B-2A via the USAF's Open Mission Systems (OMS) architecture.

During the trials the Spirit received targeting information from Northrop Grumman's Gulfstream G550 intelligence, surveillance and reconnaissance test bed via a battle management command and control (BMC2) ground node.

An OMS-compliant auto-routing function aboard the B-2 then replanned its mission and it conducted a simulated attack. The contractor had integrated the mission-planning auto-router into the B-2A in around six weeks.

Weapons

The B-2A's two side-by-side weapon bays are each capable of carrying up to 30,000lb (13,608kg) of ordnance on eight-round RLAs. Alternatively, four SBRAs enable the aircraft to engage as many as 80 separate targets.

Development of the SBRA began in January 2001 and the programme came to an end in March 2006, when the 54th SBRA was delivered.

For conventional missions the Spirit can carry sixteen 2,000lb GBU-31 JDAMs; eighty 500lb GBU-38 JDAMs; 36 Combined Effects Munitions (CEMs), GATOR Mine, Sensor Fused Weapons (SFW) or Wind Corrected Munition Dispensers (WCMDs); 16 AGM-154 Joint Stand-off Weapons (JSOWs) or AGM-158 Joint Air-to-Surface Standoff Missiles (JASSMs); eight GBU-28, GBU-37 or EGBU-28 5,000lb penetrator bombs; or a pair of 30,000lb GBU-57 MOPs.

For the nuclear mission, 16 B61 or B83 nuclear free-fall bombs can be carried. The B-2 had been compatible with the AGM-129A Advanced Cruise Missile (ACM), but it was withdrawn in 2012.

***Above:** Only 16 B-2As are maintained as combat ready at any given time, the remaining four are usually undergoing routine maintenance or being upgraded. The Spirits have flown around 120,000 hours since they entered service.* *Don Logan*

Under Flexible Strike, the B-2A will be configurable with multiple weapons for maximum strategic nuclear and conventional flexibility. Planned weapons integration efforts include the precision-guided B61-12, advanced versions of the GBU-28E/B and GBU-28B/D bunker busters; AGM-158B Joint Air-to-Surface Standoff Missile-Extended Range (JASSM-ER); a 5,000lb version of JDAM; 2,000lb GBU-56 Laser JDAM; GBU-53/B Small Diameter Bomb II; and the planned Long Range Standoff (LRSO) cruise missile, which will replace the nuclear standoff capability lost when AGM-129 was removed from service.

Under current plans the B-2A will remain in service until 2058 timeframe and operate alongside Northrop Grumman's new B-21A Long Range Strike Bomber from the mid-2020s. Continued upgrades will ensure its viability.

***Above:** Returning from a strike on a communications complex in downtown Baghdad, a Spirit makes its way towards Diego Garcia in the Indian Ocean. While it's obvious this photograph was taken in daylight, the USAF has never revealed whether it has deployed stealth aircraft on daytime missions.*

Breaking Down the Black Budget

Michael Schratt gives his thoughts, on the shadowy world of black project funding.

"IN THE councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist."

With those historic words in his farewell address to the nation on January 17, 1961, President Dwight Eisenhower warned of the dangers associated with runaway military-industrial programmes.

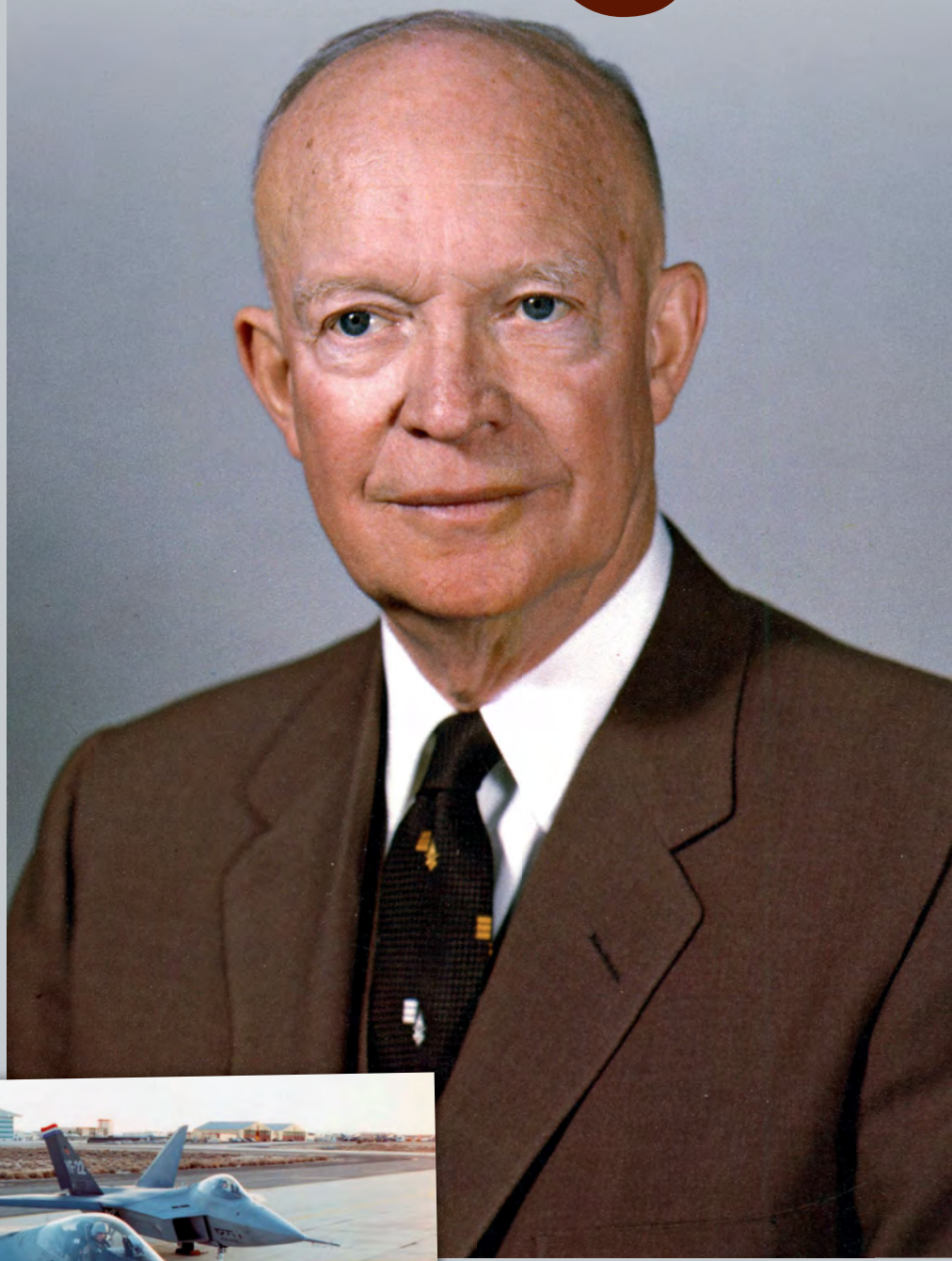
In today's world of cloak-and-dagger behind the scenes activity, the US 'black budget' has grown exponentially. Having little Congressional oversight and virtually no public scrutiny, programmes developed within the black world enjoy almost unlimited access to financial backing regardless of their probability of success.

So what can be gleaned about the black budget from public sources? And could some of these programmes be declassified without representing a threat to the national security of the US?

National accounts

Article 1, Section 9 of the United States' Constitution reads: "No Money shall be drawn from the Treasury, but in Consequence of Appropriations made by Law; and a regular Statement and Account of the Receipts and Expenditures of all public Money shall be published from time to time."

In other words, according to the Constitution, it is the law for the government to make available to the public (from time to time) an accounting of how much money is spent.



Above: *President Dwight D Eisenhower warned the US against unwarranted influences by the military-industrial complex, which could lead to the misplaced use of power and funding in the name of secrecy.*

Left: *The development of Lockheed Martin's YF-22 advanced tactical fighter (ATF) was one of four programmes to share $6bn funding in the late 1980s, the other three were owned by Northrop.* *USAF*

The government actually complies with this very important form of 'checks and balances'. Every January, the Department of Defense (DoD) submits its annual budget report for the concurrent fiscal year. The unclassified version of this report is available to the public at the Library of Congress.

But the Constitution gave no details of exactly how the money should be tracked or mandated, requirements that would reveal exactly what it was spent on. Technically, the wording in the Constitution is too vague, which opens up the possibility for rampant fraud, waste and abuse.

Reagan's years

By 1987 the black budget had tripled under the Reagan administration. Procurement funding for the Pentagon's black budget for Fiscal Year (FY) 1988 was a staggering $35 billion. During the 1980s, secrecy appeared to be standard operating procedure, with billions disappearing on projects that might never see the light of day.

Indeed, Reagan's desire to 'classify everything' was so prevalent that in 1982 he signed an executive order that essentially revised the procedure for holding onto military secrets.

It stated that in balancing the public right to know against the government's power to keep secrets, secrecy should carry more weight.

However, according to former House Armed Services Chairman Les Aspin and ranking minority member William Dickinson, 70% of the black budget could be declassified without impacting national security. Unfortunately, few federal investigators have the security clearance necessary to audit black programmes.

According to a statement by Thomas Amlie (a Pentagon missile expert) published in the Detroit Free Press on February 8, 1987, there are three primary reasons for black programmes:

1. You're doing something that should genuinely be secret
2. You're doing something so damn stupid that you don't want anybody to know about it
3. You want to rip the moneybag open and get out a shovel, because there is no accountability whatsoever.

A 31-year-old systems engineer interviewed for the same Detroit Free Press article said: "In a black project people don't worry about money. If you need more money, you got it, if you screw up and you still need more, you got it, you just keep pouring more money into the thing until you get it right.

"The incentive isn't there to do it right the first time. Who's going to question it?"

One can only imagine the catastrophic consequences that might result if government agencies like the FAA or Department of Transportation, or ICBM missile silo contractors, operated under the same work ethic.

UNCLASSIFIED

Department of the Air Force
FY 1994 R D T & E Program

Exhibit R-1

Appropriation: 3600 F Research Development Test & Eval AF

Line No	Program Element Number	Item	Act	FY 1992	FY 1993	FY 1994	Se c
				Thousands of Dollars			
155	0208021F	Electronic Combat Support	4				U
156	0208042F	HAVE FLAG	4				U
157	0303605F	Satellite Communications Terminals	4	1,544	4,145	1,399	U
158	0305137F	National Airspace System (NAS) Plan	4	4,176	6,672	18,773	U
159	0305142F	Applied Technology and Integration	4				U
160	0305158F	CONSTANT SOURCE	4	11,893	7,062	3,245	U
161	0305887F	Electronic Combat Intelligence Support	4	1,841	1,790	2,004	U
162	0401840F	MAC Command and Control System	4	10,975	12,082	11,361	U
				4,420,435	4,180,317	4,910,864	
		Tactical Programs					
163	0102830F	Classified Program	5				U
164	0301305F	Intelligence Production Activities	5				U
165	0301310F	Foreign Technology Division	5				U
166	0301313F	Defense Dissemination Program	5				U
167	0301314F	Infrared/Electro-Optical/Dir. Energy Weapons Processing and Exploitation	5				U
168	0301315F	Missile and Space Technical Collection	5				U
169	0301317F	SENIOR YEAR Operations	5				U
170	0301324F	FOREST GREEN	5				U
171	0301339F	Intell Telecom and Defense Special Security Sys	5				U
172	0301357F	NUDET Detection System	5		2,564		U

***Above:** A Department of the Air Force document dated 1994, listed a number of classified programmes including FOREST GREEN and SENIOR YEAR Operations, details of both are unknown.* *via author*

Deleted costs

Another technique to conceal black programmes is to delete their overall costs from the unclassified budget. They are given vague and nondescript code names to hide their true purpose.

In addition, the Pentagon keeps many black programmes secret from Congress, the General Accounting Office and its own auditing agencies.

According to a report published in Aviation Week and Space Technology on August 17, 1992, the black budget burns through more than $100m dollars a day on intelligence gathering, covert operations and weapons development, with no civilian oversight.

Could some of that funding go to support the US's faltering infrastructure or improve its education system?

A 1990 House Armed Services Committee study revealed that Congress reviews only 5 to 10% of programmes that have a Special Access Required (SAR) designation.

Examining the annual unclassified DoD budget report, it's easy to see how black programmes can be concealed. For example, the Research, Development, Test & Evaluation (RDT&E) Programs (R-1) budget report for FY 1994 contains multiple programmes with no procurement funding listed.

They include 'Senior Year' and 'Forest Green': classifying the name, function or cost of a particular black programme automatically forces less privileged legislators to vote 'in the dark' to approve the project.

Black budget monitoring increased in 1980 when President Carter leaked information that the US Air Force was developing a 'stealth bomber'; in 1981, Northrop's stock soared.

During the Reagan administration, black budget funding rose to $22.4 billion for FY 1987. Of this, $6 billion went to four black aircraft projects – the B-2 'Stealth Bomber', YF-23 Advanced Tactical Fighter, Advanced Tactical Aircraft and F-117A 'Stealth Fighter'.

Northrop owned three of the programmes, but ultimately lost out on the Advanced

Northrop lost the ATF contract with its YF-23 proposal. Rumours persist that despite the two prototypes being retired, a strike variant was developed to fulfil a role similar to that of the F-111. If true, this aircraft still remains classified. *USAF*

Above: ***During the Reagan administration the annual funding for US black programmes tripled to a staggering $35bn in 1998. Some have still not been made public.***

Tactical Fighter, which went to Lockheed and the F-22A Raptor, while the Advanced Tactical Aircraft (ATA) contract went to the ill-fated McDonnell Douglas/ General Dynamics A-12 Avenger II.

The USAF originally proposed buying 132 B-2s at a cost of $277m apiece, for a total of $36 billion. In the end, however, Northrop built only 21, at the staggering cost of $2.3 billion each.

Secret costs

According to Ben Rich (Lockheed Skunk Works director, 1975-91), keeping programmes secret can add anywhere from 10 to 15% to their overall cost. This includes the construction of fortified buildings, extra guards, security clearance, logistics and shuttling workers to and from classified facilities.

Within the murky world of secret defence projects there are three main categories: Special Access Program (SAP), Unacknowledged Special Access Program (USAP) and Waived SAP. Congress, and possibly the President, may be unaware of the existence of a Waived SAP.

Aside from payments to defence contractors, spending within the intelligence community has also increased dramatically. For FY 1988, the CIA's budget was $2.5 billion and the secretive National Reconnaissance Office (NRO) consumed $4 billion. But these pale into insignificance compared to the National Security Agency (NSA), which spent an estimated $10 billion.

In fact, under a secret directive signed by Reagan, the NSA has access to the computer systems of the IRS, Social Security Administration and every other civilian government agency. No law or charter has established limits on the NSA's power since its secret formation by President Truman in 1952.

Military and security operations have always required that some information remain classified. For example, the specific mathematical equations used in the formation of the atomic bomb should always be kept under wraps.

In more modern times, the exact specifications of the electronic countermeasures used by US military aircraft are rightly kept secret, as are the communication frequencies used by US forces in Afghanistan.

But more aggressive control on classified spending is clearly required. On September 10, 2001, for example, CNN reported that former Secretary of Defense Donald Rumsfeld had testified before Congress that the Pentagon could not account for $2.3 trillion dollars. Where did that money go?

The public should demand a more proactive accounting of DoD expenditures. In the end, even the highest elected political leaders are not above the law and additional public scrutiny would go a long way to increase faith in both the Constitution and the administration.

Above: ***The cost of one operational B-2A is estimated to be around $2.3 billion, which many analysts believe is a conservative figure. Military observers point out that the bomber is worth more than its own weight in gold.*** *Northrop Grumman*

COMBAT AIRCRAFT SPECIAL

UNITED STATES AIR FORCE AIR POWER YEARBOOK 2016

Produced by the *Combat Aircraft* team; the US Air Force Air Power Yearbook is the ultimate guide to the world's most powerful air arm. Packed with features on latest aircraft capabilities, famous squadrons and the personnel that fly and maintain the various types, plus a detailed unit and aircraft air power review. This 100-page publication is a must-have for USAF aviation fans.

FEATURING:

F-22 on the front line
A review of the Raptor's combat debut over Syria and recent deployment to Europe.

40 Years of exercise' Red Flag'
A review and tribute to the world's most famous exercise.

Bayou Militia
A unit review of the F-15Cs of the 122nd Fighter Squadron Louisiana ANG

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North American Silent Night Attack Aircraft

UNACCEPTABLE LEVELS of aircraft losses endured by the US during the Vietnam War – particularly to Russian supplied SA-2 *Guideline* SAMs – became a major cause of concern for American aircraft manufacturers.

As the war dragged on, the Office of Naval Research proposed a feasibility study to explore low radar cross-section stealth technology which could be applied to a combat strike aircraft.

The design had to address four important areas of the new technology: radar, infrared, acoustic and visual. The government-funded programme ran from 1971 to 1973.

North American Aviation submitted its proposal for the new naval attack aircraft in 1972, known as Silent Night, which was a tailless flying-wing configuration.

Although it was never built, North American Aviation's concept pre-dated Lockheed's Have Blue concept by three years, making it one of the very first government-funded stealth aircraft programmes.

NORTH AMERICAN SILENT NIGHT ATTACK AIRCRAFT

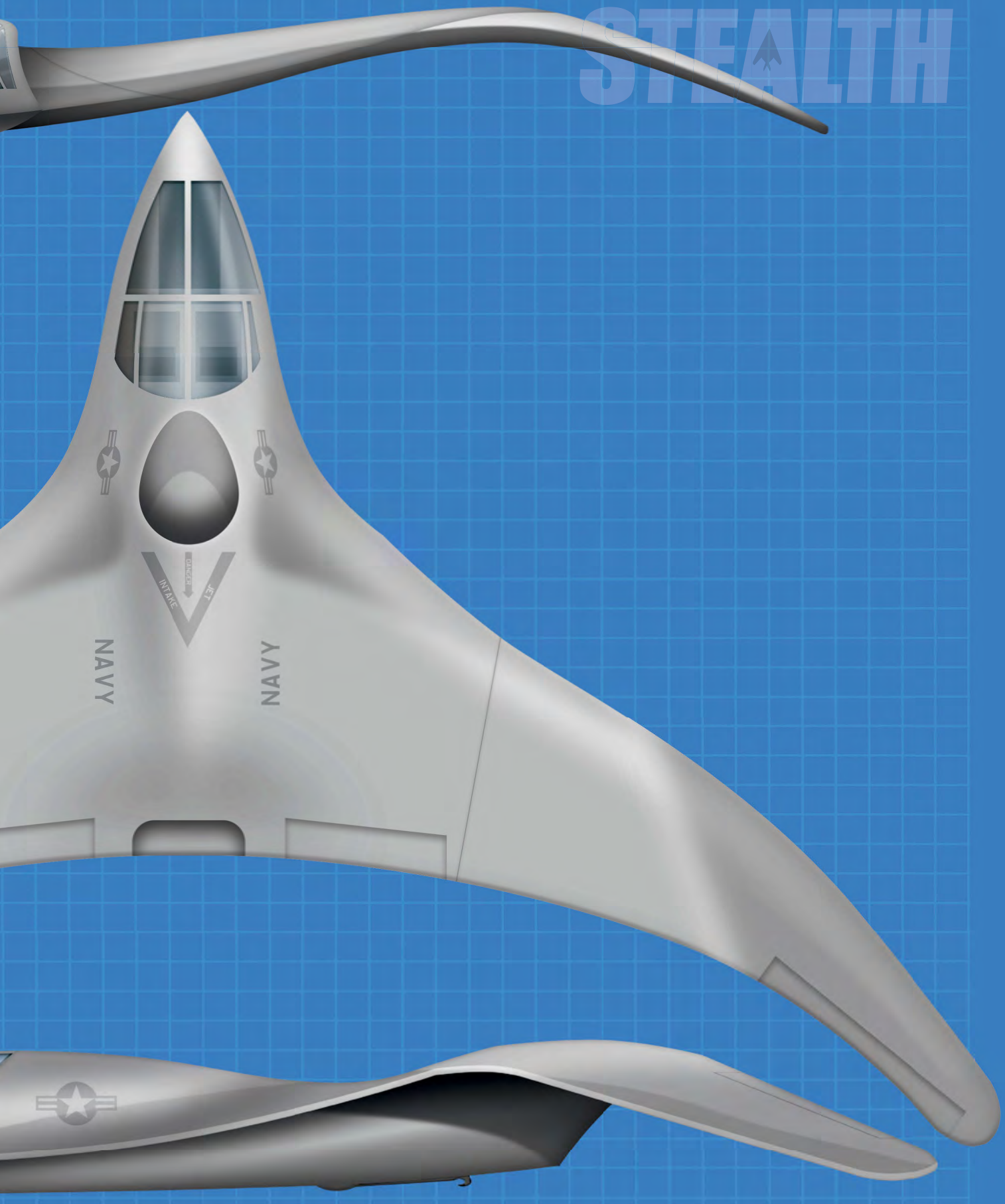
Cockpit: The pilots sat side-by-side in a cockpit layout similar to the Grumman A-6 Intruder's. A later proposed design switched to a tandem-seat arrangement similar to the F-14 Tomcat's. The instrument panel would have been fitted with a 5in x 7in CRT display which received information from a single KA Band mapping radar in the forward nose area and two steerable low-light television scanners. A retractable FLIR turret with laser designating capability was also located on the forward fuselage.

Engine: To reduce the RCS, its twin-pack turboshaft-driven ducted fan engine was buried deep inside the body of the aircraft, with a single air-intake mounted on the top of the fuselage.

Landing Gear: Silent Night would be fitted with a typical US Navy-style heavyweight tricycle undercarriage complete with a nose-mounted carrier launch bar.

Weapons: Armament consisted of two AGM-65 Maverick air-to-ground, or two AGM-78 anti-radiation, missiles; the aircraft had no defensive weapons of its own.

Wings: A tailless configuration with 'all moving' wingtips, from the outset Silent Night was intended for carrier-based operations. Two large wing-fold joints were located midway along the wings, just after the rear fuselage flaps.



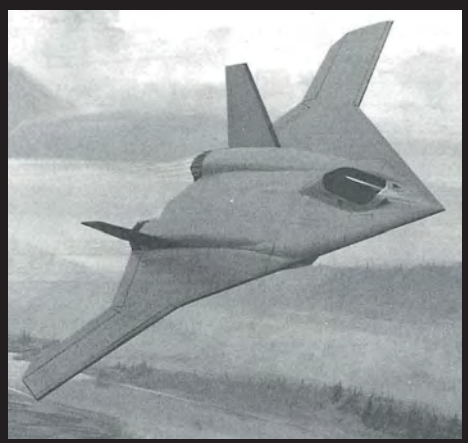
Andy Hay/www.flyingart.co.uk

Stealth UK Style

Tim Ripley looks at the UK's efforts to develop stealth technology and apply it to advanced combat aircraft or drones.

DURING THE early 1980s, British scientists, aviation industry executives and senior RAF officers became aware of the highly classified work under way in the US to develop the F-117 and B-2. The Royal Aircraft Establishment at Farnborough was at the forefront of linking into this US government and industry work, but it was in the north west of England that Britain's stealth centre of excellence began to form.

Aircraft engineers and scientists at the Warton site of what was then British Aerospace (BAe) were asked to examine the technology and come up with something that could be applied to future RAF aircraft. Not surprisingly this work was highly classified, but the company put a model of a flying wing aircraft on display at the 1990 Farnborough Airshow. It appeared to have stealth, or low observable (LO) features incorporated into its shape, which was designed to make radar waves bounce off in the 'wrong direction', rendering it invisible.



During the 1980s British Aerospace proposed a number of stealthy strike aircraft, exotic-looking examples such as this never got beyond the drawing-board.

At the same time, BAe was developing radar absorbent material (RAM) for application on existing aircraft ahead of a dedicated machine that incorporated stealth technologies dependent on airframe shape. In the late 1980s and early 1990s the focus of Warton's work was the Experimental Aircraft Programme (EAP), which evolved into the Eurofighter Typhoon. The new fighter employed RAM to reduce its radar cross section (RCS) by limiting radar returns from its large engine intake, cockpit and areas of the fuselage and wing.

The company's successor, BAE Systems has since developed considerable expertise in RAM, with a team of engineers at its Towcester, Northamptonshire site

The full-scale test aircraft known as Replica was first sighted on the BAE Systems radar measurement range at Warton in Lancashire on February 28, 2014. *Neville Beckett*

Scientists and engineers at BAE Systems have lifted the lid on some futuristic stealth technologies that could be applied to military aircraft in service in 2040 or earlier. One design unveiled is The Survivor 01. *All images via BAE Systems unless stated.*

Corax is intended as a multi-role ISTAR system demonstrator. It first flew on January 25, 2005. The UAV uses a modular design that provides commonality with other British UAVs.

specialising in the design, measurement, test and production of materials designed to reflect, transmit or absorb microwave radiation at optimum levels.

It currently advertises a wide range of RAM products including foam, coatings for composite and metal structures, fabrics, internal structures and hoods for radio antennas for incorporation into aircraft, ships and land-based military equipment.

UK Skunk Works

Lockheed led the work on the first US stealth aircraft at its famous Skunk Works. The Palmdale, California facility brought scientists, engineers and test pilots together into a single organisation under conditions of great secrecy. Its first products – the U-2 and A-12 spy planes – changed the course of the Cold War and in the 1970s work began there on the F-117, the world's first operational stealth aircraft.

British Aerospace and its successor, BAE Systems, had an equivalent group, although its base on the south side of Warton aerodrome's main runway, lacked the glamour and mystique of Palmdale and its associated Area 51 where US stealth aircraft were designed, built and tested.

It's known as BAE Systems' Advanced Technology Centre, and is complete with aircraft assembly hangars and office facilities. The Ribble estuary (just a few hundred metres from the centre's hangar) adds to the impression of isolation.

British Aerospace's work on stealth aircraft began in earnest in the mid-1990s, when

BAE Systems predicts that 3D printers will become advanced enough to allow printing during a UAV's mission; aircraft parts damaged in flight could 'heal' themselves. The Transformer 03 would be one such operational UAV to use this technology.

the company and the Ministry of Defence (MOD) began funding the design of models for testing in wind tunnels, and in the RCS measuring facilities and infrared ranges at Warton. This effort was intended to inform the design of an aircraft to replace the Tornado GR as the RAF's primary long-range strike platform between 2013 and 2017.

A veil of secrecy was thrown over the work, but the first hints it was under way came in 1995, when Flight International reported on the High Agility Low Observable (HALO) project, which it said was intended to produce a full-scale flying demonstrator by 2000.

It now seems this effort had been formally launched in 1994, with £20 million of joint company and MOD funding; its initial designs were dubbed Replica and Testbed. The Defence and Evaluation Research Agency (now the Defence Science Technology Laboratory) was heavily involved in the programme. Images of the Replica model appeared in 2014 when it was spotted being moved around Warton on a truck. It looked very similar in shape to the F-22 Raptor, with 'V' tail, blended wing and curved fuselage surfaces, as well as an internal weapons bay.

According to media reports, the Replica airframe included carbon fibre composite skin panels. Its canopy was treated to avoid radar energy reflecting from within the cockpit environment and its radome exhibited an unusual curved edge.

Above: The Mantis medium-altitude long-endurance UAV utilised a limited amount of stealth technology on its fuselage, but this was compromised by its additional role as an unmanned military transport. Below: Ten years of research and development by BAE Systems produced Taranis, which is similar in size to a Hawk jet trainer.

UK Joins JSF

After the 1997 Defence Review, the UK began moving towards joining the US project that eventually became the F-35 Lightning II Joint Strike Fighter (JSF). Thus the need for the UK to build its own stealth fighter slipped down the MOD's agenda and Replica never became a flying demonstrator. The ministry put its Tornado replacement work on the back burner, under the banner of the Future Offensive Air System. BAE Systems released several artists' impressions, but the concepts they illustrated did not seem to have moved forward at any speed.

After BAE Systems was formed in 1999, its participation in the JSF programme accelerated as it became involved in designing the aircraft's rear fuselage. Perhaps, more importantly, its engineers and experts in advanced manufacturing were involved in developing the processes needed to manufacture the F-35's unique fuselage, which incorporates many stealth features. BAE Systems was instrumental in defining the manufacturing processes that ensure the F-35's main fuselage structures and coverings can be brought together with an exceptionally high degree of precision, leaving the aircraft's skin absolutely smooth for maximum stealth effect.

Warton's drones

For much of the 1990s, the British Government and BAe had considered drone development in co-operation with the US as the best course of development. But when the UK became involved in the JSF this view changed. Such co-operation came with

***Above:** Taranis was flight tested in complete secrecy at the Woomera Test Range in South Australia in August 2013. The autonomous UAV is scheduled to be operational by the late 2030s.*
***Below:** Raven was intended to demonstrate that a stealthy UAV could be developed rapidly if required. The entire programme took just nine months to complete, from early design to first flight.*

many strings attached, in particular limiting exports and work with other countries.

Stealth, LO or low signature technologies are so important to combat aircraft design that no serious aerospace company or air force wants to be left behind in the technology. The British Government therefore put it at the heart of its December 2005 Defence Industrial Strategy and began funding BAE Systems' work on future stealth technology. This culminated in the project that eventually created the Taranis unmanned combat aerial vehicle (UCAV).

Any future UCAV would be required to penetrate deeply into enemy airspace and would require a high level of LO to protect it from radar, infrared and other forms of surveillance. BAE Systems was already working on UCAV technology demonstrators to get up to speed on the technology, building the Raven and Corax air vehicles.

Taranis design at Warton got under way quickly and the first metal was cut in 2007, ahead of the aircraft's unveiling, under considerable security and a sound and light show, in July 2010. Photography was banned and visitors were warned not to attempt to even sketch Taranis. Those without top secret security clearance were permitted to come no closer than 50ft (15m) of the aircraft.

Taranis made its first flight over Australia's Woomera Test range in August 2013 and further sorties could take place within efforts to jointly develop a UCAV with France over the next decade.

From the limited perspective of those who have seen Taranis and the selected imagery realised of test flights in Australia, it seems the air vehicle incorporates high-level stealth in all its aspects. Taranis lacks vertical control surfaces, significantly reducing RCS, and from the forward aspect it has sharp wing leading edges, to dissipate radar waves. It also appears to have shielded engine exhausts, to reduce infrared signature.

The work with France kicked off in 2010 and accelerated earlier this year with a formal agreement to build a demonstrator under the €2 billion Future Air Combat System (FACS) project.

Future UK Stealth

Royal Air Force and Royal Navy pilots and groundcrew are now in the US, learning to operate the F-35B variant of JSF. When they return to Britain in two years' time as the fully formed 617 'Dambusters' Squadron, they will have the distinction of being members of the first RAF unit to operate a purpose-designed stealth aircraft.

The visit of six F-35s to the UK for July's Royal International Air Tattoo and Farnborough International Airshow, gave the public an opportunity to see them up close on the ground and during flying displays. The F-35B's rear aspect is evidently less stealthy than its forward or side aspects and its hot engine exhaust is also clearly visible, making it vulnerable to air- or ground-launched heat-seeking missiles.

The F-35B will not replace Typhoon in the air defence role; when a Typhoon replacement is required, perhaps in 20 years or so, an all-aspect stealth aircraft will be needed. This might be an Anglo-French future combat aircraft – sources close to the initial FACS work say it could easily be expanded and applied to a future manned aircraft. That warplane, should it come to pass, would take British stealth technology to a new level.

***Above:** The HERTI series of UAVs are intended to be the next generation of stealthy utility UAVs for the British Armed Forces. The various models can be configured for specific missions.*
***Below:** The F-35B's rear aspect is far less stealthy than that to the forward or side, the hot engine exhaust was clearly visible during its demonstration at RIAT this year.* *Lockheed Martin*

Neptune's Stealthy Hawk & that Raid...

David Cenciotti describes the mysterious MH-X helicopter revealed by Operation Neptune's Spear, the 2011 raid that killed Osama Bin Laden. He speculates as to what the secretive helicopter may look like in service with the 160th Special Operations Aviation Regiment (SOAR) 'Night Stalkers'.

THE FIRST images of the remains of a helicopter used by US Navy SEAL Team Six in Operation Neptune's Spear, the raid that killed Osama Bin Laden, caused a stir among aviation experts and enthusiasts globally. The images, which began appearing on social media on May 2, 2011, were of parts that seemed to belong to an unknown type.

The tail rotor had an unusual cover that could have been anything from an armour plate to a noise reduction cover, sheltering motion-control technology already tested by NASA and used to input low-frequency variations in rotor blade pitch angle. The aircraft's rotor blades were flatter rather than wing shaped, and its paint finish extremely similar to the anti-radar paint and radar-absorbing material used on modern stealth fighters. Nothing was common to the Black Hawk, Chinook or Apache helicopters.

According to the few official statements released in the aftermath of the raid,

***Above:** An artist's impression of the mysterious MH-X Stealth Black Hawk helicopter revealed during Operation Neptune's Spear, the raid that killed Osama Bin Laden at Abbottabad, Pakistan, on May 2, 2011.* ***Below:** A more realistic rendering showing how the 'Silent Hawk' might look like, created by applying engine shields, rotor covers and adding an extra main rotor blade to a standard MH-60 Black Hawk.* *AviationGraphic.com/TheAviationist.com*

the helicopter did not suffer a failure, but skittered uncontrollably in the heat-thinned air, forcing the pilot to crash land. As he did, the tail rotor hit one of the 12ft (3.7m) walls surrounding Bin Laden's Abbottabad, Pakistan compound.

Whatever the cause of the crash (human error while flying on night-vision goggles (NVGs), wake turbulence generated by the other helicopter on the mission, or 'recirculation' are all possibilities), the SEALs reportedly attempted to destroy it to hide its technology. But the tail section survived because it had fallen outside the compound. Thus the world was treated to a glimpse of an advanced technology developed in the Cold War era, when the US ran a series of 'black' programmes aimed at easing Special Operations teams' task of penetrating Soviet installations.

It is extremely difficult to say whether the helicopter involved in Operation Neptune's Spear (also known as Operation Geronimo, after the code word used to designate Bin Laden) was an existing type heavily modified or a new design. But the images prove that Osama Bin Laden was such an important target, his elimination justified the use of a deeply secret technology.

A possible shape

I began studying the possible shape of what soon became known as the 'Stealth Black Hawk' or 'Silent Hawk'. With the help of AviationGraphic.com artist Ugo Crisponi, I imagined what the aircraft would have looked like after combining the tail section and main rotor revealed in the photographs, engine shields, rotor covers, additional main rotor blade (for a slower main rotor speed and reduced noise) and some imagination.

The fairly inaccurate initial sketch resembled an S-76 more than an MH-60, but even after subsequent reviews it appeared to be consistent with an in-depth study already in the public domain and freely available on an official US military website.

Issued in 1978 by Sikorsky Aircraft Division for the US Army Research and Technology Laboratories, this interesting document is entitled *Structural Concepts and Aerodynamic Analysis for Low Radar Cross Section (LRCS) Fuselage Configurations*. These first attempts at providing the UH-60 with stealth capabilities were useful for imagining possible modifications to the aircraft's profile.

The Applied Technology Laboratory developed three LRCS fuselage configurations, both based on the tail surfaces and main rotor pylon fairing of the baseline UH-60A. The first configuration slightly altered the baseline fuselage around the cockpit, producing a modified nose and slightly increased overall length.

The second changed the fuselage shape to create a cross section similar to that of a truncated triangular prism, with increased overall length, width and height, and a narrower cockpit space. A vertical climb rate of such an aircraft would be only 15% that of the baseline UH-60A.

The third extended a canted, flat-sided shape along the fuselage. The narrow cockpit that resulted forced the pilot and co-pilot seats closer together, while the windscreen's rake is believed likely to have caused visibility problems.

The document did not identify a specific LRCS configuration for a radar-evading Black Hawk, but the structural concepts developed for the study and aerodynamic analysis suggested a shape more like that of an F-117 than a more modern stealth aircraft, such as the F-22 or F-35.

The low observability project may have not been the only study to inspire the shape of the Stealth Black Hawk used in 2011. Some sources suggest that some of the MH-X technology may have come from the YEH-60B Stand-Off Target Acquisition System (SOTAS), a Black Hawk variant designed to detect moving targets on the battlefield and downlink the information to an army ground station. The only SOTAS built for the US Army (flown in the early 1980s, before the programme was cancelled in favour of the E-8 JSTARS) had retractable main gear.

Other modifications may have been inspired from other prototypes then under development, including the Army's Advanced Composite Airframe Programme (ACAP), which aimed to develop an all-composite helicopter fuselage lighter and less costly to build than the predominantly metal airframes in general use.

Further work was probably done to reduce the overall RCS, perhaps including a flat

STEALTH HAWK BIN LADEN

Above: ***Based on the remains of the tail section, the author with the help of aviation artist Ugo Crisponi, created this sketch of what the stealthy chopper would have looked like after being upgraded to make it stealthier and quieter.***

windscreen with a gold layer for electrical continuity, fairings covering the push rods and main rotor hub, retractable inflight-refuelling probe and IR suppressors.

In 2015, *Relentless Strike*, a book by award-winning defence journalist Sean Naylor provided details on the history of MH-X. He says the two helicopters involved in the Bin Laden raid were the first prototypes of a classified programme aimed at making the Black Hawk less visible to radar. A series of modifications was required, but left the helicopters tricky to control under certain conditions.

The prototypes were built and tested at Area 51, Nevada, but the programme was cancelled. When the need to infiltrate Pakistani airspace emerged, the two experimental airframes were selected to deliver the SEALs into Abbottabad.

Inspired by the successful outcome of the operation in Pakistan, the 160th SOAR 'Night Stalkers' flew the surviving MH-X in Syria, where it took part in the failed July 4, 2014 attempt to free American journalist James Foley and other captives from Daesh.

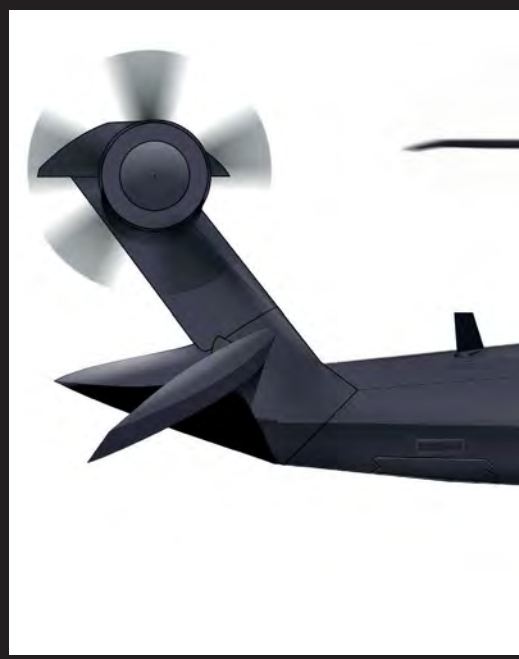
The presence of possible MH-X derivatives was also rumoured in a daring raid that killed high-level Daesh operative Abu Sayyaf at Deir Ezzor. He was eliminated at a position southeast of Raqqa, eastern Syria, on the night of May 15/16, 2015.

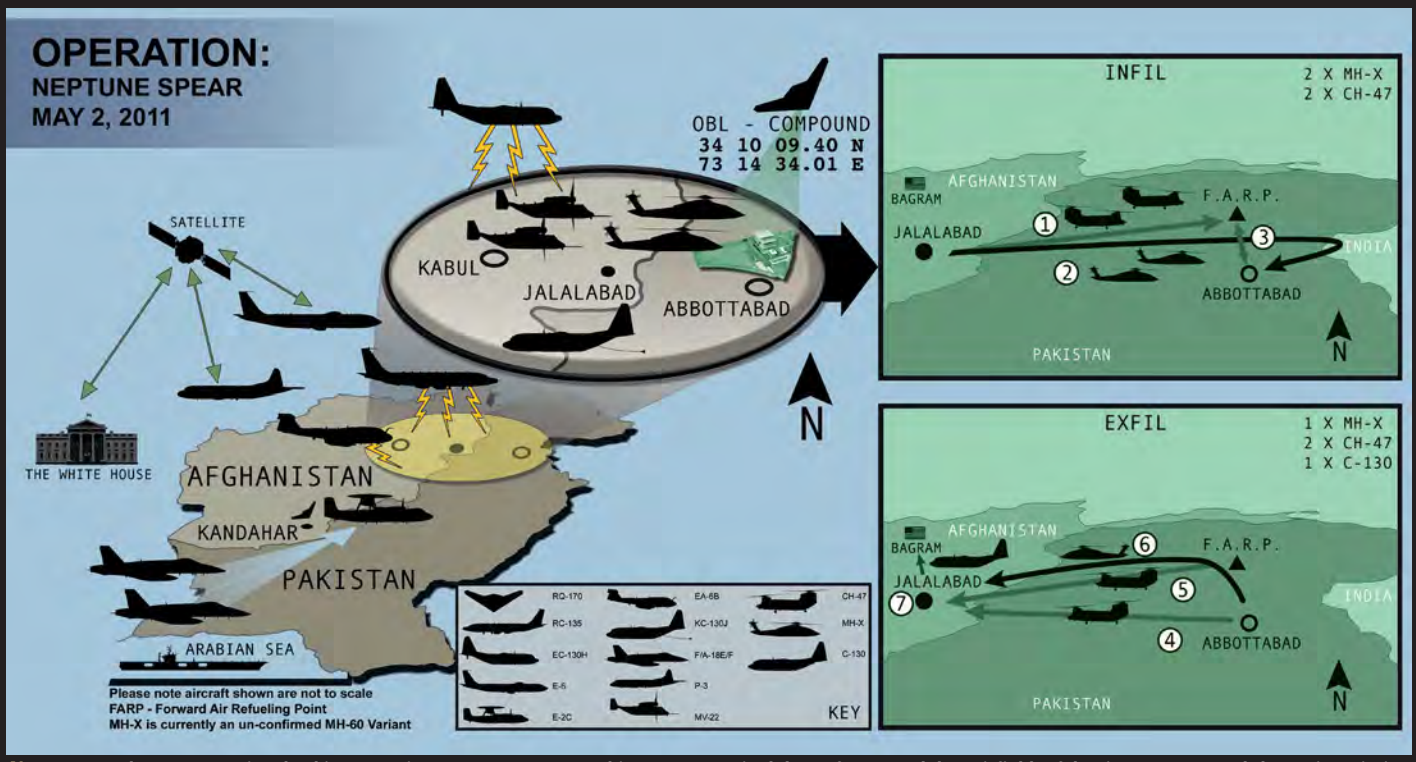
Neptune's Spear

Based on information released by official sources and details in first-hand accounts of the Neptune's Spear raid (including *No Easy Day*, by former Navy SEAL Matt Bissonnette), it is possible to draw a 'picture' of the SEAL Team Six attack.

The two MH-Xs departed Jalalabad air base, Afghanistan, and flew to Abbottabad using callsigns 'Chalk 1' and 'Chalk 2'. They infiltrated Pakistani airspace from the east. A pair of MH-47s was on standby at a forward air refuelling point

Although the US Navy SEALs Team Six attempted to destroy the radar-evading helicopter that crash-landed inside Bin Laden's compound, the tail rotor of the MH-X survived, revealing the existence of a 'black helicopter'.





*Above: **Several assets were involved in Operation Neptune's Spear – this RQ-170 Sentinel drone from Kandahar airfield, Afghanistan, supported the entire mission by providing real-time full motion video (FMV) of the target area before and during the raid.***

(FARP) north of Abbottabad. These had brought in the personnel and materiel required to establish the FARP, and a combat search and rescue team.

In the event, one of the MH-47s flew to the compound to recover the crew of the crashed MH-X then flew directly to Jalalabad. The second MH-47 and surviving MH-X returned to Jalalabad via the FARP. An RQ-170 Sentinel drone from Kandahar supported the entire mission with detailed real-time full motion video of the target area.

Along with the 160th SOAR's helicopters, many other aircraft are likely to have flown in support of Operation Neptune's Spear, including the RC-135 Rivet Joint, gathering signals intelligence; the EC-130H for localised jamming of Pakistani communications; the E-2 and/or E-3 for airborne early warning, and airspace and tanker management; and the E-6, acting as an airborne command post and relaying orders directly from the White House.

Later, an MV-22 carried Osama Bin Laden's body from Jalalabad to USS *Carl Vinson*, where the former al Qaeda leader was buried at sea. SEAL Team Six travelled from Jalalabad to Bagram in an MC-130.

Other aircraft might well have been involved, waiting on the ground or in the air, the latter probably having launched from one or both of the aircraft carriers stationed in the Persian Gulf at the time – USS *Enterprise* and USS *Carl Vinson*.

Israeli postscript

In a 2012 report written for a US global intelligence newsletter, F Michael Maloof, a former Pentagon senior policy analyst, suggested that the Israeli Air Force was equipped with the Stealth Black Hawk, as used in Operation Neptune's Spear. He said the aircraft had been used to drop Iranian dissidents into Iran to gather intelligence on Tehran's nuclear programme.

An early sketch showed an aircraft more resembling an S-76 civil helicopter than an MH-60. When the author published his first artist's impression of the MH-X on his website, it became the focus of attention for model kit companies, documentary producers and videogame makers who were all keen to capitalise on the media frenzy surrounding the Bin Laden raid.

Monsters from the East

AFM's Glenn Sands examines China's emerging fifth generation stealth fighters.

MAINLAND CHINA – the People's Republic of China (PRC) – is undergoing a process of great change and has accelerated development of its military, in particular its aeronautical output. The Western myth of it being an underdeveloped peasant nation could not be further from the truth as the nation now jostles for position as one of the world's most influential economic powerhouses.

While China exports significant quantities of locally designed and manufactured combat aircraft around the world, its military aviation remains generally little understood and detailed information is hard to come by.

What is widely acknowledged is the size of the People's Liberation Army Air Force (PLAAF), the third-largest in the world after those of United States and Russia.

The PRC is making great efforts to invest in the development and introduction of an entire range of new combat types, such as the JH-7, J-11 and J-10. But it is the recent emergence of 'stealth-looking' fifth-generation prototypes and test aircraft

Above: ***China's J-20 stealth fighter stunned the West when the prototype was revealed. But it was in November 2009 that General He Weirong, then Deputy Commander of the PLAAF, hinted to the media that a fifth-generation fighter was in development.*** *Illustration Bai Wei*

that has taken the West by surprise.

Given the high level of secrecy surrounding China's frontline military aircraft, details on the latest fifth-generation fighters, such as the XXJ and similar projects, have been the subject of speculation and debate among defence analysts in the US and Europe.

Sources and Speculation

In early 2002, according to a senior development manager within the China Aviation Industry Corp I (AVIC-I), Sheyang (SAC) was chosen to research and develop the next heavyweight fighter for the PLAAF.

Conformation of the programme was revealed to the international defence market at the Dubai Air Show a few months later when AVIC-I released a short video of wind tunnels tests at their facility.

The model under test closely resembled Lockheed Martin's F-22A Raptor but with F-16-style wings. Based on the J-13, work on the project, dubbed Concept 1993 (some believe the project was called 'Fighter D') began in the early 1990s but reports in the West say the aircraft

Above: ***The seventh J-20 prototype '2016' first flew on September 2015.*** *All images via Chinese Internet unless stated* *Below:* ***The FC-31's debut at Air Show China in Zhuhai in 2014 involved an eight-minute demonstration that revealed little of the aircraft's full performance.*** *Piotr Butowski*

did not progress beyond wind tunnel testing, with a model of a new design exhibited at Zhuhai later in 2002.

This disappeared shortly after to be reworked, equipped with higher-rated engines and a tri-plane style wing arrangement and dubbed the J-19. But the project was not developed beyond the drawing board when it lost out to the Chengdu (CAC) J-20 design.

Development of the new PLAAF fighter was initially given to SAC, which took on the responsibility of building the stealth aircraft, but problems quickly emerged – which have never been fully disclosed – and the project was hurriedly passed to CAC in mid-2008. Major work was to be carried out at Chengdu's Factory 132 with SAC only supporting the aircraft's development through limited subcontracting work.

Typical of China's secretive military aviation development projects, little emerged ➤

about the new aircraft until a television interview in 2009 with General He Weirong, Deputy Commander of the PLAAF, who said China's first stealth fifth-generation fighter was to undergo test flights "soon" and that it would be operational in eight to ten years.

He added that the selected design followed the four 'S' capabilities: stealth, super-cruise, super manoeuvrability and short take-off.

In late 2009 it emerged that at least one full-scale mock-up had been built, and by mid-2010 two prototypes were under development. Chief designer for the J-20 programme was Yang Wei, along with deputy director Zhang Jiago.

Despite a trickle of information reaching the West, mainly through sources within the US Naval Intelligence community, there was little indication the project was making real progress.

In late 2011 the first photographs of the J-20 emerged along with supporting evidence that at least two prototypes had been completed. Carefully timed to coincide with a January visit to China by the then US Defense Secretary Robert Gates, perhaps? On January 11, being an auspicious day in a very superstitious country, the first flight of one of the J-20s 2001, took place from CAC's home base at Chengdu Huangtuanba. However, it lasted little more than 20 minutes and little information would have been gained from this short test hop.

After the successful first flight, a photo was released from a celebratory banquet revealing the programme was called Project 718 and the pilot for the flight had

Above: ***The planform of the J-XX suggests it was heavily influenced by Northrop's failed YF-23 and Sukhoi's PAK-FA T-50. No weapons bays can be discerned, indicating this airframe is still in the development stage.***
Below: ***The second J-20 prototype '2002' was rolled out in March 2012 and first flew on May 16. It was later grounded and modified with a new nose to house an AESA radar before re-joining the flight test programme in mid-2013.***
Bottom: ***A rare detailed view of J-20 '2016' as it taxies at the Chengdu Aircraft Industry Corporation's Huangtianba facility.***

A composite image which shows how different the third prototype '2011' is from '2001' the first J-20 built.

been Li Gang – for analysts in the West, the openness in which China's military was handling this project was a surprise.

Amateurs outside CAC's facility – in the heart of the city and easily viewed from countless locations – took early photos of the new aircraft and leaked them on the internet. It was impossible to hide anything under test at the facility.

By all accounts, the Chinese authorities monitoring all internet traffic in the country then gave up blocking images of the J-20, which meant the new fighter jet was revealed to the West far earlier than planned. For many outside China, it was seen as a new policy of openness by the PLA; how far it goes, regarding future military programmes, remains to be seen.

By early 2012 four airframes had been built – numbered 2001, 2002, 2011 and 2012, the last acting as a static test airframe. Around this time the J-20 received the unofficial names Black Eagle, Black Silk or Wei Long (Mighty Dragon in Chinese).

It was clear to observers that the new aircraft incorporated similar design aspects to the F-22 Raptor, with a sharp diamond-shaped nose and a huge frameless single-piece canopy. Other areas of the J-20 mirrored Mikoyan's cancelled 1.44 prototype, in particular the rear section with four fins.

Stealth was the driving factor behind the design, which required a blended fuselage, clean fuselage-to-wing joints and slab-sided intakes similar to the F-35 Joint Strike Fighter. Panel lines around the fuselage and undercarriage and weapons bays feature serrated edges as seen on the F-117 years earlier.

Although both of the early demonstrator aircraft, 2001 and 2002, were superficially similar, their engines were different – and presumed to be an indigenous design in one and Russian-supplied in the other.

Reports suggested either the NPO Saturn 117S series engine, already in use on the Su-35 (although deliveries to China remain unconfirmed) or its predecessor, the AL-31FN, most likely the Series 3 – a variant that does not generate sufficient power for the J-20 to super-cruise, which it will not be able to achieve until the planned WS-15 turbofan enters service.

Adding to the confusion were the slightly different exhaust petals seen on various photos of the J-20s, which led to speculation that at least one of the early prototypes was re-engined with the indigenous Shenyang Liming WS-10A Taihang powerplant prior to its maiden flight as an interim solution to enable flight testing to continue uninterrupted.

The avionics suite in the J-20 was predicted to be the latest fire-control radar, presumed to be an active electronically scanned array (AESA)-type set known as Type 1475. The system is undergoing trials on a heavily modified Tu-204C airliner at the China Flight Test Establishment (CETE) at Xi'an-Yanliang airfield. ➤

An underside view of J-20 '2015'. The AL-31FN turbofan engines are evident in this view – it is planned to replace these with WS-15 engines in the near future.

The J-20's large central weapons bay accommodated the upgraded PL-12C and PL-15 long-range AAMs, while side bays in the intake ducts (similar to those on the F-22A) will house short-range PL-10 short range infra-red missiles.

The second prototype, rolled out in March 2012, began pre-flight testing the following month and completed its maiden flight on May 16. A week earlier, 2001 flew after being grounded for minor modification work before going to the CETE for more flight tests.

Compared to 2001, the second prototype, 2002 (renumbered 2004), had its pitot tube moved to the nose tip; and its undercarriage doors could close when the landing gear was retracted. It also featured a new light grey scheme.

A third prototype, 2011, which did not take to the air until March 1, 2012, was highly modified. Its most notable improvements were new air intakes, a completely redesigned nose section and radome, re-profiled vertical stabilisers, new dielectric panels in the forward fuselage and a redesigned canopy.

Above: ***One J-20 prototype was equipped with WS-10G engines with different jagged-edged nozzles and tiles for evaluating stealth characteristics around the exhaust area.***

A chin-mounted electro-optical targeting system (ETOS) was also fitted under its nose and the shape of the landing gear bays revised. The reworked prototype wore the now standard overall grey stealth coating.

It quickly became clear why 2011 had been delayed and the new modifications were incorporated into the pre-series production aircraft which followed 2011's early test flights. The next aircraft, 2012, flew on July 26, followed by test example 2013 on November 29 and then prototype 2015 on December 19.

By the end of the year (2014) four new J-20s had flown for the first time. A seventh aircraft, 2016, was photographed undergoing ground tests on September 11 at the Chengdu Aircraft Design Institute and took its maiden flight on September 18, 2015. An eighth example, 2017, took to the air for the first time on November 24, 2015.

CAC ended the year by unveiling the first low-rate production J-20, 2101, on December 26.

Above: ***Technicians swarm around the third J-20 prototype – they give scale to this enormous fighter.***
Below: ***This J-20, '2012', is one of four pre-series prototypes. It made its maiden flight in July 2014, and features a stealth coating, a re-designed intake and vertical stabilisers, a new canopy, and a fairing for a potential electro-optical training system.***

Engine Mystery

In the West, there is much speculation over the engines for the J-20s. With the final production WS-15 Emei at least a year away from completion, all

late examples of the J-20 are powered by the AL-31FN – with the limitations this engine brings in performance.

The situation means China continues to negotiate with Russia on the purchase of Su-35s for its Type 117S engines, which can then be reverse-engineered for the J-20.

The rate at which China rolled out two J-20s within a month suggests the aircraft is nearing the early stages of low-rate initial production (LRIP), which could be achieved by the end of the year, and analysts now presume the first few J-20As will enter service with the PLAAF much earlier than predicted.

When the ninth J-20 was seen at CAC's facility last December in a canary-primer yellow, it wore the side number 2101, not 2018 or 2019. This new serial followed the typical sequence already used on all of CAC's J-10 fighters delivered to the PLAAF, and is a clear indication that this J-20 was the long anticipated LRIP airframe. It is expected to be sent to the CETE at Xi'an-Yanliang for flight testing.

Mighty Moves

As the J-20 enters LRIP, the PLAAF is keen to get the aircraft into service – although it is clear that, despite the testing undertaken already, when the new definitive engine is finally ready, much of the certification and testing will need to be repeated.

Delays with the engine may have led to the announcement on China's Phoenix TV news programme by aircraft designer Dr Song Wencong – who was responsible for the J-10's design and mentored J-20 designer Yang Wei – that "the export of advanced Chinese military technology is prohibited. This is to keep J-20's fifth-generation technology out of hostile hands".

Suspicions persist that China's J-20 is produced using America's F-35 data stolen by Chinese hackers in a similar cyber-attack to one that helped with the JC-31 design. Song continued: "If one day the United States decides to export the F-22, China might consider lifting its ban as well."

The reason for the ban, according to Song, is that if American allies possess F-22s, China's allies need J-20s to keep the balance of power in "certain regions" in the world.

Once setbacks with the powerplants are resolved, the J-20As are expected to enter operational service around 2018 to 2019. Without question, they will present a significant impact in the balance of air power in Asia's Far East and western Pacific region. ➔

Taking to the air for the first time on November 24, 2015 was the eighth J-20 '2017'.

Above: ***The J-20 showcases modern Chinese military technology, and '2101' is the first airframe from the inaugural production batch. At least one J-20 squadron is expected to be fully equipped by year's end.***

Jon Lake looks at China's other stealth aircraft, the Shenyang J-31 multi-purpose medium fighter

Shenyang

***Above:** After each display at Zhuhai in 2014, the FC-31 taxied back to its hangar located well away from the public area.* *Piotr Butowski*

THE SHENYANG J-31 (or FC-31 Fourth-Generation Multi-Purpose Medium Fighter) is the new player on the international fighter block. First flown on October 31, 2012, and revealed to the public in November 2014 at the Zhuhai Air Show, it is a twin-engined, mid-sized, low observable tactical jet fighter being developed by China's Shenyang Aircraft Corporation.

There has been confusion as to exactly where the J-31 came from and how and why it was created, and even over what it was designed to do. Today, there is also understandable interest in how the aircraft might measure up against current Western fighters, especially frontline US Stealth fighters, which the new Chinese fighter resembles in some respects.

When photos of the J-31 emerged, there were some clear similarities with US fighters, the Chinese jet resembling the F-22A Raptor in side elevation (largely due to its canted twin trapezoidal tailfins) and the F-35 in plan form, with a similar wing, horizontal tail and forward-swept engine intakes with diverterless supersonic inlet (DSI) fairings – though the twin engines, broad, flat belly and body between the engine nozzles are reminiscent of the Raptor.

In many respects the J-31 represents what Lockheed might have produced had it been asked to produce an F-35 with no requirement for short take-off and vertical landing (STOVL) performance.

It was the STOVL requirement that drove the F-35's single-engine configuration and forward engine location (to keep the lift fan driveshaft relatively short and to optimise the longitudinal location of the vectoring aft lift-cruise nozzle).

It also required a voluminous bay for the lift fan and constrained the shape, size and volume of the weapons bays.

With no need to accommodate a lift fan and vectoring rear nozzle, the J-31 has two long, unobstructed weapons bays (each carrying two medium-range missiles or small air-to-surface weapons) arranged around the aircraft centreline, with a

J-31

***Above:** A half-size model in the AVIC hall at the Zhuhai airshow in 2014 illustrated a completely redesigned empennage and cropped wing tips.* Piotr Butowski ***Left:** The resemblance to the West's two fifth-generation fighters is evident in this view of the FC-31 as it turns towards the crowd during its display.* Piotr Butowski

broad, flat belly that reduces drag.

When low observability is not required, there are two heavy hardpoints and two light hardpoints under each wing.

To save weight, the J-31 uses a large number of 3D laser-printed components, including the titanium wing spars.

Russian Engines

Because there are no indigenous Chinese-made jet engines with the performance characteristics required by a low observable fifth-generation fighter, the FC-31 is powered by two Russian Klimov RD-93 engines – derivatives of the MiG-29's RD-33 turbofan.

The obvious physical similarities between the J-31 and US fifth-generation fighters have been accompanied by the revelation that, since 2007, a Chinese military unit called the Technical Reconnaissance Bureau had undertaken a large-scale cyber intelligence programme (known to US intelligence agencies as Operation Byzantine Hades) specifically targeting the Lockheed Martin F-35 Lightning II. Data was reportedly passed to the Aviation Industry Corporation of China (AVIC) and then to Shenyang.

The *Wall Street Journal* charged that the J-31 was "modelled on secret blueprints of the American F-35 stolen by Chinese cyber-spies" which, it said, had "pilfered terabytes of data about the F-35's operational capabilities".

Such charges cannot be confirmed or substantiated and many believe the J-31's similarity to the US aircraft is simply the result of its designers finding common solutions to similar requirements.

In any case, it seems likely the J-31 was influenced more by Russia than America, since there have been unconfirmed rumours that a team of Mikoyan designers ➤

***Above:** An optical sight, similar in shape to the IRST used by the Russian PAF-FA fighter, is fitted to a full-scale mock-up of the FC-31's forward fuselage.* Piotr Butowski ***Left:** A mock-up of the J-31's cockpit features a wide, centrally-mounted multifunction display. A head-up monitor, a data input panel and what appears to be another auxiliary display were also fitted.* Piotr Butowski

Left: ***The FC-31 is powered by two Russian Klimov RD-93 turbofans – the amount of smoke being generated is typical of this series of engine.*** *Piotr Butowski*
Below: ***Aircraft 31001 performed a short take-off with afterburners at Zhuhai. The main landing gear legs retract and rotate forward, in a similar way to the MiG-29 Fulcrum's. Note the sawtooth-shaped landing gear doors.*** *Piotr Butowski*
Right: ***The FC-31 can land in a short distance assisted by a twin brake 'chute.*** *Piotr Butowski*

assisted Shenyang in its development.

The origins of the J-31 cannot be viewed in isolation. The J-XX contest was intended to produce a new stealthy fighter or fighter-attack aircraft, and saw the Chengdu Aircraft Corporation develop Project 718 proposal, which had been selected for production as the Chengdu J-20 Mighty Dragon.

The extent to which the losing Shenyang 'J-19' (reportedly an even larger aircraft than the J-20) influenced the J-31 remains unclear and no details of the official requirement that resulted in the J-31 have been revealed.

There has been speculation that the J-31 may have been developed as a lower-cost complement to the planned J-20 or a multi-role, tactical aircraft to serve alongside the more focused Chengdu aircraft.

The first photos of a model of what we now know as the J-31 appeared in September 2011. The aircraft, in two-tone grey disruptive camouflage, was prominently marked as F-60 and decorated with AVIC Shenyang logos on the forward fuselage.

In June 2012, photos and video clips emerged of the static test airframe being moved on a truck on the highway from Beijing to Shenyang, though it was heavily wrapped in a camouflaged tarpaulin and lacked many components, including the trailing edge control surfaces and the vertical and horizontal tails.

Images of the real aircraft, in the shape of the first prototype, appeared over the weekend of September 15-16, 2012, apparently taken at Shenyang's own airfield. They clearly showed the serial 31001, leading most analysts to conclude that the new type was designated J-31, rather than F-60 or J-21, as some had expected.

A blurred photo uploaded prior to September 18 to the China Military Report website apparently showed the aircraft airborne. However, it subsequently became clear that the ten-minute maiden flight did not take place until October 31, 2012 after a high-speed taxiing test when the aircraft briefly became airborne. Prototype 31001 flew with its landing gear down, accompanied by a pair of J-11 chase aircraft and has continued a limited test programme, returning to flying in February 2013 after a brief lay-up.

With the prototype flying, China had two stealthy fifth-generation fighter designs in testing at the same time – something only America had achieved previously and a fact that provoked a frenzy of interest among US and Western analysts, with renewed concerns about China's growing military capabilities and the possible shifting of power in the Pacific region.

About the same time as the J-31 prototype began its flight test programme, in November 2012, AVIC displayed a quarter-scale model of the aircraft at the China International Aviation & Aerospace Exhibition labelled simply as an 'Advanced Fighter Concept', though industry sources and China's state-run media confirmed it represented the J-31 from Shenyang.

The aircraft was described as being designed to deliver a highly stealthy configuration at low cost, with a heavy weapons load capability, over a wide combat radius; and AVIC said it was being developed "for the international defence market", with no suggestion it might be adopted by the PLA Air Force.

In September 2013, reacting to suggestions the J-31 might eventually replace the J-15 (Sukhoi Su-33) as China's primary carrier-based tactical aircraft, Rear Admiral Zhang Zhaozhong told the People's Daily the J-31 had never been built with China's military in mind, and that it was highly unlikely that the PLA would ever operate J-31s from its aircraft carriers.

Instead, he explained, the J-31 was designed for export to China's strategic partners and allies, particularly those that could not purchase the F-35 due to price or US export restrictions.

The primary contenders for the new type would seem to be Pakistan (with which China previously jointly developed the JF-17/FC-1 Thunder tactical fighter) and Iran. China, and especially the country's aviation industry, desperately wants to generate more export sales, though AVIC may have wider and more complex ambitions.

Lin Zuoming, AVIC's General Manager, has said China wants to make its own stealth

fighter available to countries that don't have access to the F-35: "The next-generation air forces that are unable to buy the F-35 have no way to build themselves up. We don't believe the situation should be that way."

Some reports suggest the aircraft could be offered with Russian weapons, which may have greater appeal and credibility in some markets and which would obviate the need to compromise technical details of Chinese weapons systems that Beijing might want to hold back for the PLA Air Force's exclusive use.

On December 30, 2013, a leading Chinese media outlet reported the J-31 would be redesigned to have ground attack capabilities, perhaps indicating it will be acquired for the PLA Air Force as the 'low' element in a high-low mix with the more capable J-20, as well as by export customers. In Chinese service it could replace the non-stealthy Su-30MKK and fill the gap in close air support between the Xian JH-7 and the expensive Xian H-6 strategic bomber.

Show Debut

The J-31 was publicly unveiled during Airshow China on November 12, 2014, where the prototype was the highlight of the flying display. At Zhuhai, it was billed as the FC-31 – an export designation – rather than as the J-31, which would be the putative PLA designation.

In the past, it has also been referred to as the F-60 and the J-21 in some media reports, and the names Snowy Owl, Gyrfalcon and Falcon Eagle have all been associated with the type.

Behind the hype and nationalistic chest-beating which naturally surrounded the first public air show appearance by a Chinese stealth fighter, some were critical of the J-31's air show performance. They felt the FC-31 seemed to bleed energy excessively and that the pilot seemed to struggle to keep the nose up even in relatively gentle manoeuvres, relying heavily on use of the afterburners. And this was in a clean and lightly loaded aircraft.

Others point out that the J-31 is still relatively immature and that its flying display was therefore understandably "incremental and measured".

There are some reasons for believing that a production J-31 or FC-31 could differ significantly from the prototype first flown in October 2012, possibly offering improved performance and enhanced operational capabilities, and a half-scale model of the aircraft shown in the AVIC Exhibition Hall during the 2014 China International Aviation and Aerospace Exhibition at Zhuhai featured a number of planned changes, upgrades and improvements to the type.

These included a range of radar cross-section reduction measures, with clipped tailfin and wing trailing edge corners for 'edge alignment', completely redesigned vertical fins and a single-piece frameless cockpit canopy.

The model also featured redesigned, stealth-optimised engine nozzles, perhaps indicating an aspiration to fit more powerful engines which could allow the aircraft to super-cruise. They could be the 100kN Guizhou WS-13A – which is an improved variant of the JF-17's powerplant.

"If fitted with either of the two types of our newly developed engines, the J-31 will be more advanced than the US F-35," AVIC President Lin Zuoming told China Daily.

Rear Admiral Zhang Zhaozhong, who has expressed his belief that the J-31 is "too heavy", reportedly said in a speech in Xiamen on November 17, 2014 that it will take China several years to develop its own engines, highlighting digital engine controls as being difficult and "not something that can achieve success in a short time".

The new FC-31 model also had a stealthy sensor bulge on the underside of its nose, housing some kind of electro-optical/infrared sensor system. But while the J-31 looks like the F-35, it may not have the same capabilities, despite the boasts of its backers.

But Lin Zuoming told China Central Television the J-31 could defeat the F-35. "When the J-31 takes to the sky, it can definitely take the F-35 down. That's a certainty."

There have also been Western reports that the J-31 will be a match for existing fourth-generation fighters like the F-15 Eagle, F-16 Fighting Falcon and F/A-18 Super Hornet.

However, although the J-31 has a configuration resembling that of the F-22 Raptor and F-35 Lightning II, there is more to stealth than an aircraft's plan form and outer mould line, and it is impossible to gauge how low the J-31's radar cross-section might be without knowing the exact characteristics of the materials used or the aircraft's internal structure.

Nor can we really assess how well the J-31 suppresses its own infrared signature, including the heat signature of the engines.

In addition, fifth-generation fighter capability is about more than signature management. The ability to super-cruise is also important (the F-35 cannot) while super manoeuvrability has also been listed as a core fifth-generation capability.

Sensor performance, sensor fusion and network centric operations are also key and it remains to be seen whether the J-31 will have a modern AESA radar and high-bandwidth, low-probability-of-intercept data links.

The J-31 is essentially a technology demonstrator project – the production version is likely to be very different.

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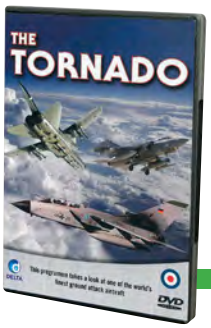
The Tornado DVD



The Tornado was jointly developed by the United Kingdom, Germany and Italy, and first flew on the 4th August 1974. A total of 992 Aircraft were built with production finishing in 1999. As well as the three main operators, Tornados were also bought by RSAF (Royal Saudi Air Force).
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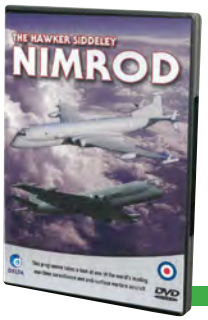

The Hawker Siddeley Nimrod was direct development from the De Havilland Comet. Mainly designed for maritime operations, the Nimrod was the successor to the Avro Shackleton and took over the maritime role in the early 1970s.
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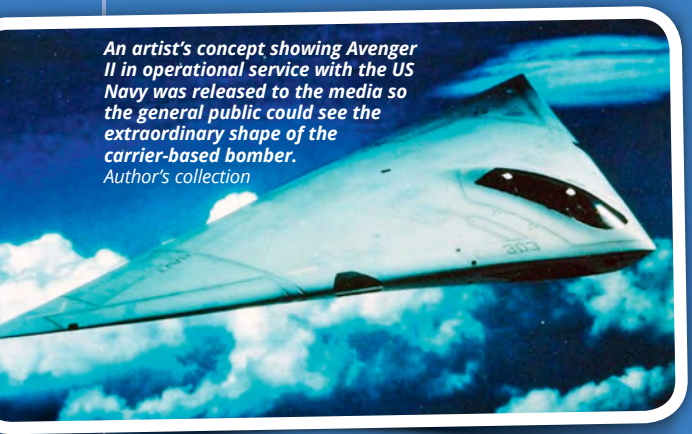
The Flying Dorito

The McDonnell Douglas/General Dynamics A-12 Avenger II

Nicknamed 'The Flying Dorito' because of its shape, the A-12 Avenger II could have brought the capabilities of a stealth bomber to an aircraft carrier deck. But cost overruns and engineers' failure to resolve technical problems saw the project cancelled amid controversy which still remains a quarter of a century later. *AFM*'s **Glenn Sands** looks at what might have been...



An artist's concept showing Avenger II in operational service with the US Navy was released to the media so the general public could see the extraordinary shape of the carrier-based bomber. *Author's collection*

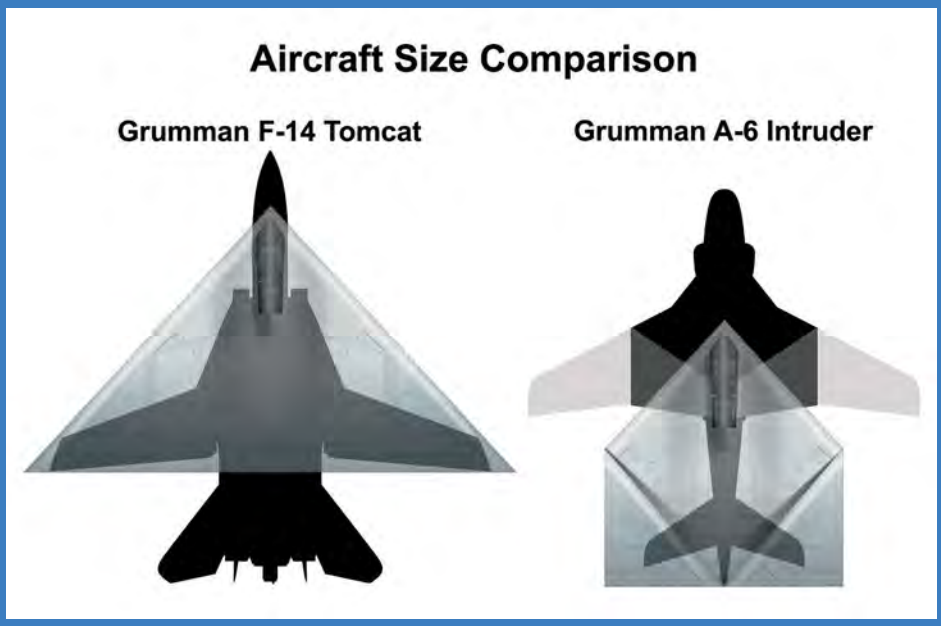
THE US Navy's A-12 Avenger II Advanced Technology Aircraft (ATA) was proposed by McDonnell Douglas and General Dynamics as an all-weather, carrier-based stealth bomber to replace the Grumman A-6E Intruder in the mid-1990s.

Plans called for the A-12 to incorporate more advanced stealthy characteristics than the F-117A and carry a significantly greater payload. Some 620 were to have served with USN, and 228 in USMC, squadrons – and at one time the USAF considered buying 400 to replace the F-111. Estimated cost per aircraft was $100m.

The A-12 was designed to fly faster and further than the Intruder and carry its weapon load internally to reduce drag and maintain a low RCS. Being a later generation aircraft, it was expected to be more reliable than the Intruder and need half the maintenance man-hours when deployed aboard a carrier.

But it proved to be the

During the development of the A-12, the two companies involved produced several adverts that were published across the aerospace press. It was an attempt to gain public backing for the aircraft. *Author's collection*



Left: Although stealth was the lead design influence in the A-12, the US Navy specified it had to be similar in size to its current carrier-based aircraft so it would fit onto flight deck lifts. *Andy Hay/www.flyingart.co.uk*
Below: Lacking the traditional tailfin, the unconventional Avenger II was an exceptionally clean-looking aircraft. *Author's collection*

most troublesome of the new American stealth aircraft, owing to extensive use of composites on the airframe. The materials did not yield the anticipated weight savings, and some structural sections had to be replaced with heavier metal components, meaning each aircraft exceeding its weight by 30 tons – 30% more than its design specification and close to the limits that could be accommodated on USN aircraft carriers.

Additional problems were discovered with the Avenger II's complex Inverse Synthetic Aperture Radar system, which was linked to its advanced avionics components, neither of which 'talked' to one another during testing.

At the time of Defense Secretary Dick Cheney's Major Aircraft Review in late 1990, the full scope of the problems had not been revealed to the review board. The only decisions made were to slow the rate of production and drop the numbers planned for the USMC, which left the USN with a bill for the original 620. Cheney also decided to delay the Air Force purchase, planned for between 1992 and 1998, for more than five years.

Shortly after, contractors on the A-12 programme publicly revealed it was facing serious engineering problems and a $2bn cost overrun, which would delay the maiden flight by more than a year (to late 1991) and substantially raise the unit cost per aircraft.

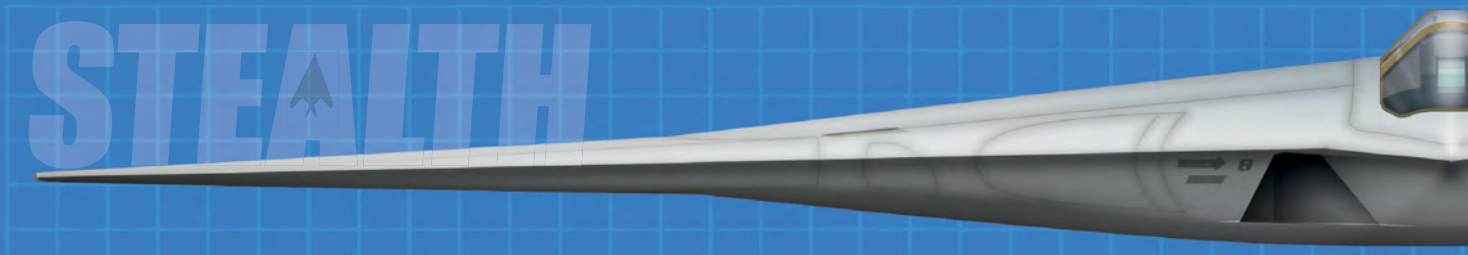
The added weight meant the A-12's performance offered little improvement over existing aircraft then flying from carrier decks, although backers of the programme claimed its stealth characteristics meant it would fly 'invisible', so a loss in performance was irrelevant.

As the cost of the programme spiralled and the radar problems continued, it was estimated that simply resolving the issues would consume up to 70% of the Navy's budget for the aircraft. Following a design review completed in October 1990, the A-12's first flight was rescheduled to early 1992. In December 1990, it was envisaged that 14 Navy aircraft carriers were to be equipped with a wing of 20 Avenger IIs each. But a government report released a few weeks before these announcements said serious problems remained with the development of the aircraft and the project faced a $2bn cost overrun.

In December 1990, Cheney told the Navy to justify the programme and deliver reasons why it should not be cancelled. Its response, and that of the contractors, failed to persuade him not to cancel the project – and on January 7, 1991 the entire A-12 Avenger II programme was terminated.

The US Government believed the contractors could not complete the A-12 and instructed them to repay most of the $2bn spent on its development – but McDonnell Douglas and General Dynamics disputed the demand in a federal court. The reasons for the cancellation have been debated ever since and remain controversial for those involved in the development of The Flying Dorito.

Above: The cancellation of the A-12 in January 1991, meant that F/A-18C Hornets – such as this example from VFA-83 'Rampagers' – became the main carrier-based strike aircraft for the US Navy after the A-6 Intruder was retired. *US Navy*
Below: A pair of Grumman A-6E Intruders from Carrier Air Wing Eight return to their carrier after a practice bombing sortie. It was the A-6 Intruder 'bomb trucks' that the stealthy A-12 Avenger II was intended to replace aboard the carrier. *US Navy*



THE MCDONNELL DOUGLAS/GENERAL DYNAMICS A-12 AVENGER II – 'THE FLYING DORITO'

Engines: The aircraft was to be powered by two General Electric F412-GE-D5F2 non-afterburning turbofan engines – each producing about 13,500lb of thrust – buried deep in the fuselage and fitted with mesh across the intake ducting similar to that used on the F-117A Nighthawk. Ironically, a General Electric F414 turbofan engine now powers the F/A-18E/F Super Hornet – a modified variant of the upgraded F412 version developed for the A-12.

Cockpit: The large single-piece canopy hinged to the right afforded the crew exceptional in-flight visibility. The pilot and bombardier/navigator sat in tandem, as on the F-14 Tomcat. The cockpit was described by those working on the programme as similar in layout to the F-15E Strike Eagle's, with seven Kaiser multi-function displays (MFDs) divided between the front and rear compartments. The front cockpit was equipped with a Kaiser wide-field view holographic head-up display, which displayed information directly from the Westinghouse AN/APQ-183 multi-mode radar onto the screen in front of the pilot.

Armament: The A-12 was armed with two AIM-120 Advanced Medium Range Air-to-Air Missiles (AMRAAMs) for self-defence. The concealed weapons bays could carry two AGM-88 High-Speed Anti-Radiation Missiles (HARMs) and a full complement of air-to-ground ordnance, including unguided and precision-guided bombs. Allowances were made for the A-12 to deliver nuclear weapons from its internal bomb bay. It had a weapons load of 5,160lb.

Sneeky Pete: Evidence suggests the A-12 Avenger II concept was derived from an earlier, smaller stealth prototype called 'Sneeky Pete' (see *Stealthy Secrets on the Shoulder*, p96-97), which was designed to test the stealth flying wing penetrator concept in the early 1980s. It's not clear if a classified Sneeky Pete actually flew as a technology demonstrator during the 1980s, but many aviation analysts believe it did, for a short trial period, from the Groom Lake Test Site. If actually tested, it has yet to be declassified.

Wings: A substantial wing fold mechanism at the midway point of the A-12's wingspan enabled the aircraft to equal the stowage space of the A-6 Intruder, the jet it was to replace.

The A-12 Avenger II was to be the US Navy's new Advanced Tactical Aircraft, designed to replace the A-6 Intruder.

Andy Hay/www.flyingart.co.uk

CLASSIFIED PROGRAMMES

I WAS LUCKY enough to have reported on what was undoubtedly one of the golden eras of aerospace innovation; one that was unusual, too, in that many of its most significant achievements were top secret.

I refer to a period in the 1980s and 1990s when the US aerospace and defence industry was boosted by one of the biggest injections of cash into classified research, development and acquisition activity it has ever received.

This was the Reagan era of military spending, bookended by the year in which President Ronald Reagan took office, 1980, and a date around 15 years later when the effects of the period's hike in classified expenditure had all but ended.

At its peak, around 1988, annual expenditure on the research and development aspects of US classified programmes alone was computed to be around $30 billion – at the time more than the entire annual defence budget of a major European NATO nation such as Britain, France or Germany.

This was the price that the hawkish incoming president expected to have to pay for bringing about the downfall of what he had branded the 'evil' Soviet Empire and the end of the Cold War.

Reagan's play was a bold gamble, but it worked. At the end of 1991, the Soviet Union, bankrupt of ideology and cash, announced its dissolution. In post-Cold War analysis, credit for the brokering of a peaceful end to more than 40 years of East-West standoff is rightly given, amongst a general US push to get tough on defence, to Reagan's Strategic Defense Initiative (SDI), or 'Star Wars' as it was branded at the time – as well as to the progressive policies of Soviet leader Mikhail Gorbachev.

***Above:** A four-ship of F-117As from Holloman AFB, New Mexico conducts a training flight for the benefit of the photographer. The stealth fighter's development was one of the most highly classified programmes in the United States at the time. Few outsiders were granted access to Lockheed Martin's Skunk Works during the 1980s.* *Richard Cooper*

What is less well known is that it was the upping of the ante by Reagan in deeply classified areas of defence expenditure – most notably in the field of stealth, the rendering of a 'platform' (which back then generally referred to an aircraft) largely 'invisible' to radar and other forms of detection – that played an equal if not bigger role in bringing down America's old enemy; a success that was brought about – to our great relief – without a shot being fired.

Black programmes therefore played a critical role in winning the longest, most expensive 'war' in our recent history. No wonder much of what lies at their core remains secret to this day – and, in the opinion of this writer, will remain so for decades yet; and perhaps forever.

In 1987, I became the Aerospace Editor of Jane's Defence Weekly, a magazine with a global brief and a hard-hitting news agenda to get beneath the skin of the world of aerospace and defence; to report on the good and not-so-good aspects of the sector's business practices – and at all times to get to the heart of the story.

An emerging story in 1987 was that of stealth. For several years, there had been rumours, based on the most fractional of leaks, that the US Air Force was developing a stealth fighter, that it was likely being built by the Lockheed Skunk Works and that it might be carrying the designation F-19.

The rumours were supported by sketchy evidence that a secret unit of aircraft which flew only at night was operating out of an airfield within the Tonopah Test Range, Nevada; and by two mysterious crashes – one in July 1986, the other in October 1987 – that

A Northrop Grumman B-2A awaits its next mission in the dark. Like most stealth aircraft the bomber operates under a cloak of secrecy. Information made public about the aircraft has been carefully controlled. *AirTeamImages.com/Ismael Jorda*

Smoke & Mirrors

Technology consultant **Nick Cook** takes a personal journey through the Golden Era of America's Classified Programmes.

seemed to confirm something highly secret was already operational.

The second crash took place within the Nellis Air Force Range, north of Las Vegas, a piece of government land the size of Switzerland given over to military exercising and test flying. It also plays host to Groom Lake, better known as Area 51, which has been home to classified test flying since the Lockheed U-2 first flew there during the 1950s.

The first crash, however, took place outside the range near Bakersfield, California, and was less easy to cover up – although thanks to a monumental effort, which included arrangements to seed a false trail by scattering pieces of McDonnell F-101 Voodoo at the crash site, the secrecy was maintained.

As a result, the classification surrounding the 'Stealth Fighter' held – in no small measure due to some cleverly worded denials by government officials – until November 1988, when the existence of the Lockheed 'F-117A' programme was formally unveiled via the release of an artist's impression.

The accompanying details declared the aircraft to have been operating at squadron strength 'in the black' for five years with more than 50 production examples on order.

With the development of the Northrop B-2 Stealth Bomber also ramping up, the big question in defence circles in the aftermath of the Stealth Fighter roll-out was this: what other 'black projects' might also be out there – projects so secret that they did not officially exist?

Cut to late 1992, when Jane's then technical editor for North America, the highly respected writer Bill Sweetman, filed a report on a story he had been developing for a number of years about a putative hypersonic aircraft – a replacement for the Lockheed SR-71 – dubbed 'Aurora' in media circles after it had apparently and mistakenly been exposed as a budgetary line-item in a Pentagon spending report.

Sweetman's story was based on technical evidence that Aurora was the classified embodiment of NASP (the X-30 National Aerospace Plane designed to lead to a family of military and civilian hypersonic vehicles) alongside a 1989 sighting of Aurora by an eminently qualified witness, Chris Gibson, a member of Britain's Royal Observer Corps.

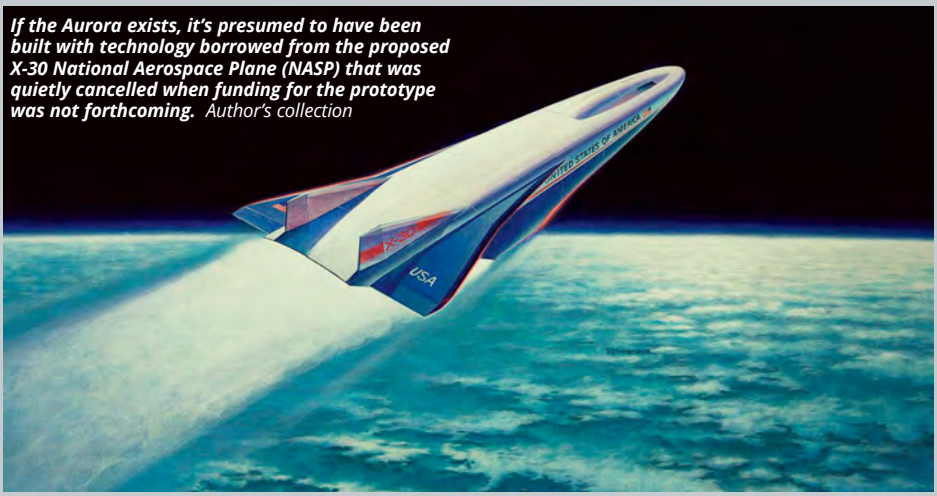
Above: ***A computer-generated image of the formation Chris Gibson witnessed in 1989, showing two F-111s flying behind a KC-135 with the alleged 'Aurora type' aircraft in the centre.*** *Glenn Sands Collection*

Gibson, while working on an oil-rig in the North Sea, spotted a large triangular aircraft in formation with F-111s and an air-refuelling tanker high overhead. There were also reports that US Government Survey seismological sensors were picking up a hypersonic aircraft "that wasn't the Space Shuttle" crossing the California coastline on its way to a landing site which seemed to map exactly with Area 51.

Increasing Evidence

Taken together, the technical and sightings indicators appeared to point to evidence that something existed, and for a while Aurora became a byword for just about anything secret that was held to be flying on moonless nights over America's southwest desert.

The stories were further fuelled by reports in Aviation Week – in particular, a celebrated October 1990 edition – which concluded, from an analysis of 45 different daylight and night-time eyewitness observations, that "at least two – but probably more – types of vehicles" beyond the F-117 and the B-2 were then under test.



If the Aurora exists, it's presumed to have been built with technology borrowed from the proposed X-30 National Aerospace Plane (NASP) that was quietly cancelled when funding for the prototype was not forthcoming. *Author's collection*

One was a "triangular-shaped, quiet aircraft seen with a flight of F-117As", another was a "high-speed aircraft characterised by a very deep, rumbling roar reminiscent of heavy-lift rockets" and a third was a "high-altitude aircraft that crosses the night sky at extremely high speed observed as a single bright light – sometimes pulsating – flying at speeds far exceeding other aircraft in the area".

The 'quiet aircraft' was later tipped, with very little evidence, to be the Northrop TR-3A; the other two looked much like the same thing: Aurora.

In 1996, I was given the opportunity to interview Jack Gordon, the head of the Lockheed Martin Skunk Works at its Palmdale plant on the edge of the Mojave Desert in California – the facility where all its work, classified and otherwise, had been undertaken since Lockheed's Advanced Development Projects (ADP) unit had moved from Burbank, Los Angeles, several years earlier.

This was a rare sanction, especially for a non-US citizen; all the more so as the interview would take place in the Palmdale headquarters building.

Given the many reports of classified aircraft that were circulating then and the prevailing view that the Skunk Works – famed for its development of the U-2, the A-12/SR-71, the F-117 and the then-emerging DarkStar stealth UAV – was responsible for many of them, I wanted to make the most of it.

Gordon, of course, was too experienced to divulge details of anything classified, but he did appear to make one genuine slip during our discussion: in the course of his 23 years with the company, he told me, he'd worked on 15 "real, flying aircraft", but, he added hastily, he could only talk about 12 of them.

His reference to these unacknowledged programmes was tantalising, but on my way out of the building, a part of the Palmdale facility that non-cleared civilians don't normally see, I saw something genuinely

arresting: a milestone chart depicting the lineage of every (divulged) Skunk Works programme, starting in the bottom left corner in the 1940s with the XP-80 and ending in the top right corner – after the F-117, after the YF-22 prototype and the DarkStar UAV – with something labelled as 'Astra'.

The artist's schematic that accompanied this unacknowledged project looked fast and pointy and when I started to ask questions about it, I was politely bundled into the waiting car.

In my attempts subsequently to discover what Astra was, I was given a public relations line that was so risible as to be surreal: Astra, I was told, was a scrapped 1970s airliner study.

There are a couple of personal postscripts to the Astra story. The first involved an interview, shortly after my talk with Jack Gordon, with Bob Widmer – then in his late seventies and still working as a consultant on unmanned combat air vehicles for Lockheed Martin at its Fort Worth plant.

Robert H Widmer had been the chief designer for General Dynamics Convair during the 1950s and was responsible for the design of the B-58 Hustler.

More germane to this story, he had been the chief architect of a Mach 6 reconnaissance aircraft called Kingfish which General Dynamics Convair had bid against the A-12 for the Mach 3-plus U-2 replacement programme in the late 1950s.

In a twist to the Kingfish story, Widmer revealed he was unable to discuss it with me – this being in the late 1990s – because it was still classified.

In other words, almost a decade after the SR-71 had first been retired, and long after the A-12 had been declassified, the design of the losing aircraft in the contest that led to both of them was still secret; and Kingfish, of course, was a design that looked a lot like the prevailing view of Aurora.

The other addendum came around a decade later when I sat down at a trade show with another former Skunk Works boss and talked to him about the Astra incident.

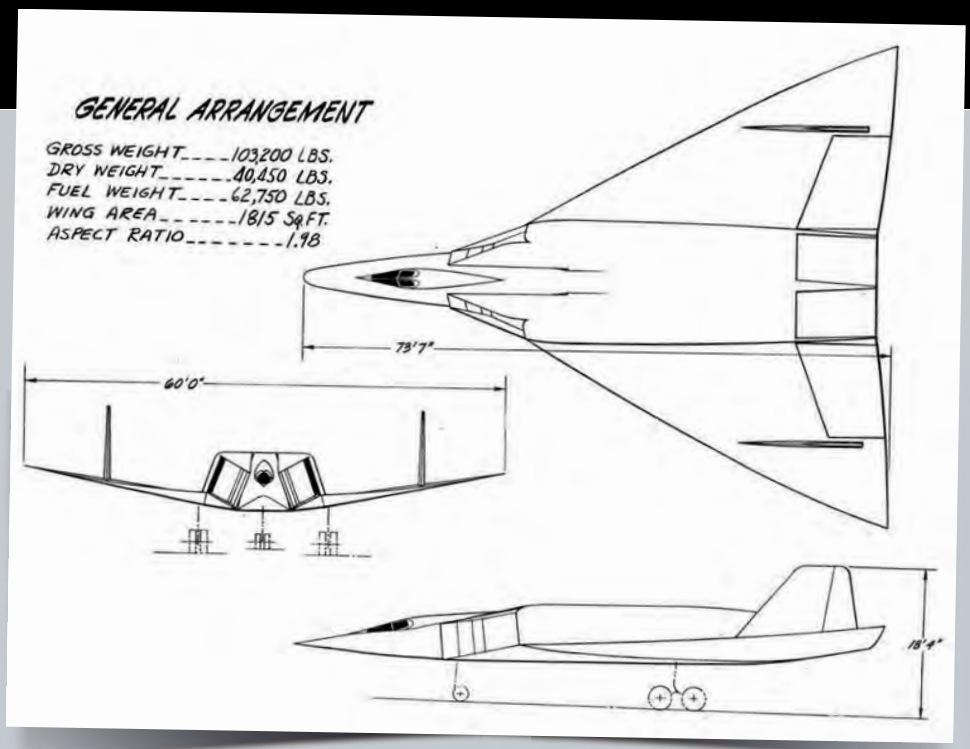
What had happened, I asked? Had it been a genuine mistake or was it rather a piece of disinformation (or a black world practical joke, even) that had been seeded there for my benefit?

Without batting an eyelid, he said it had been a genuine error (the actual words he used to describe the Astra 'screw-up' were fully expletive-laden to underline just how much of a security breach it had been) – and that, as a result, heads had rolled.

When I then asked, given the time that had elapsed since the Astra incident, when we might expect to see the results of the Astra programme, he said: "Within a few years for sure."

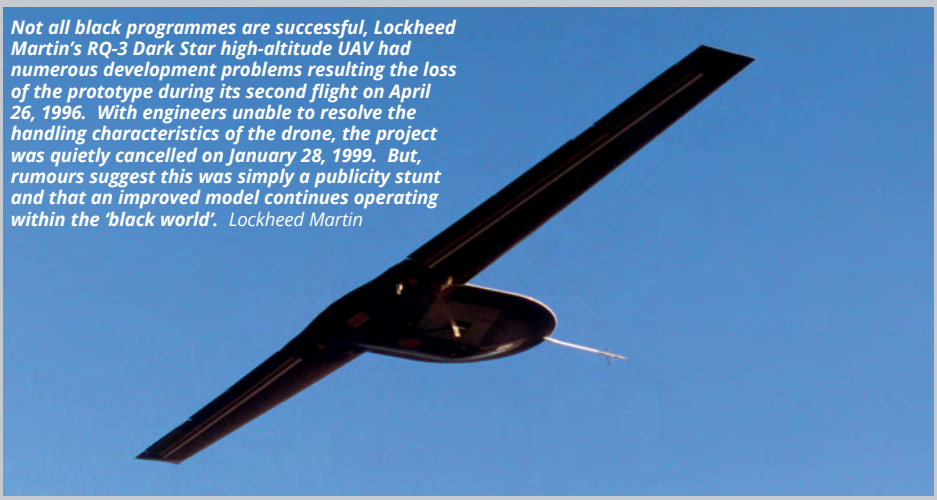
More than ten years on from that discussion, it is debatable whether anything like Astra has emerged into the light of day – I would submit that it has not.

My conclusions now on the whole thing? The 'Astra incident' was part elaborate practical joke and part disinformation – disinformation being a key element in the black world toolkit for maintaining project secrecy.



Above: ***General Dynamics Convair proposed the Super Hustler, later known as Kingfish, as a high-speed reconnaissance aircraft. It would have been capable of reaching speeds in excess of Mach 6. The design lost out to Lockheed's A-12, but information on Kingfish was classified until the late 1990s. Curiously, not all the details on the programme have been released. Defence analysts believe the Aurora has a similar configuration, which could be why information has been withheld.*** *Glenn Sands Collection*

Below: ***Area 51, Groom Lake or Water Town – whatever name was used to describe the airfield, it was home to the U-2 during its early years. The spy plane could be tested and flown far away from prying eyes, prior to the U-2s being covertly deployed overseas.*** *Lockheed Martin*



Not all black programmes are successful, Lockheed Martin's RQ-3 Dark Star high-altitude UAV had numerous development problems resulting the loss of the prototype during its second flight on April 26, 1996. With engineers unable to resolve the handling characteristics of the drone, the project was quietly cancelled on January 28, 1999. But, rumours suggest this was simply a publicity stunt and that an improved model continues operating within the 'black world'. *Lockheed Martin*

Aurora: a hoax or not?

So, what was Aurora all about? Did it exist or didn't it? By the late 1990s, the Aurora sightings had all but gone away – including the 'doughnuts-on-a-rope' contrail pictures that had appeared in Aviation Week and seemed to point to an exotic propulsion source for the aircraft, possibly a pulse detonation wave engine (PDWE) or a combined-cycle rocket/supersonic combustion ramjet (scramjet).

Watchers, who since the late 1980s had been camping out on mountain tops overlooking Area 51, had seen nothing definitive, although satellite imagery of the base, ironically taken by Soviet spy satellites and released commercially by the Russians, clearly showed Groom Lake's runway had been lengthened significantly and that there had been plenty of new infrastructure

Lockheed Martin's ASTRA

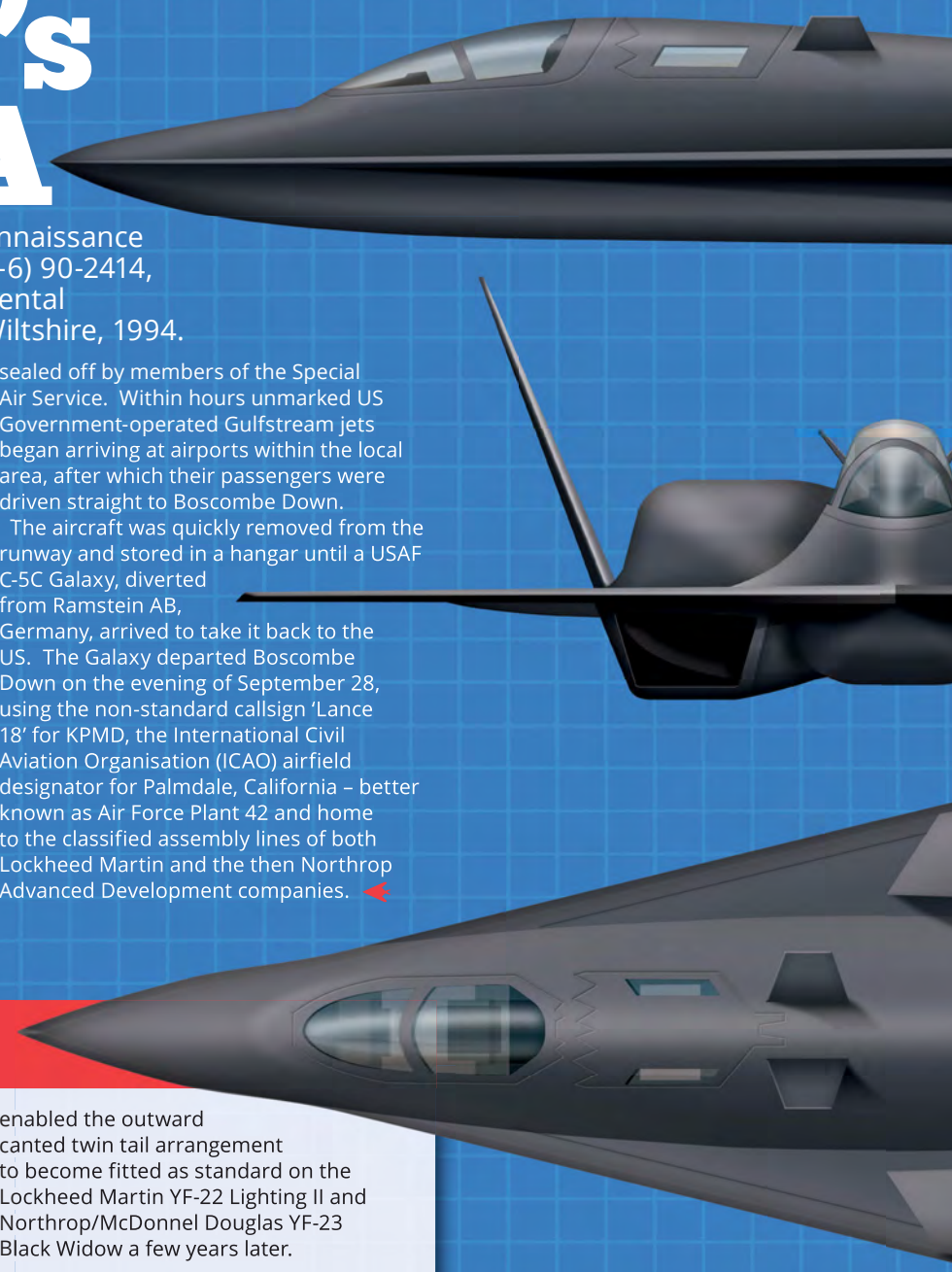
Advanced Stealth Technology Reconnaissance Aircraft (ASTRA), Air Vehicle Six (AV-6) 90-2414, Aeroplane and Armament Experimental Establishment, Boscombe Down, Wiltshire, 1994.

ALTHOUGH THERE'S never been any official confirmation as to the existence of ASTRA, there've been numerous eyewitness accounts, strange sonic booms heard over Europe and grainy images of aircraft similar in shape and design posted on the internet. The aircraft is able to fly at ultra-high speeds, Mach 5 and beyond, and operated from undisclosed sites in the US, and occasionally overseas, during late 1980s and throughout the 1990s.

The most significant sighting of AV-6 occurred on the night of September 26, 1994. Taking off from Runway 23 at the Wiltshire test establishment, a malfunction of one of the engines following the application of military power caused the American crew to abort. Eyewitnesses say the aircraft's nose-wheel collapsed as a result of the excessive braking, leaving AV-6 stranded on the runway.

What followed was one of the largest security operations in the UK, with areas inside and just outside Boscombe Down sealed off by members of the Special Air Service. Within hours unmarked US Government-operated Gulfstream jets began arriving at airports within the local area, after which their passengers were driven straight to Boscombe Down.

The aircraft was quickly removed from the runway and stored in a hangar until a USAF C-5C Galaxy, diverted from Ramstein AB, Germany, arrived to take it back to the US. The Galaxy departed Boscombe Down on the evening of September 28, using the non-standard callsign 'Lance 18' for KPMD, the International Civil Aviation Organisation (ICAO) airfield designator for Palmdale, California – better known as Air Force Plant 42 and home to the classified assembly lines of both Lockheed Martin and the then Northrop Advanced Development companies.



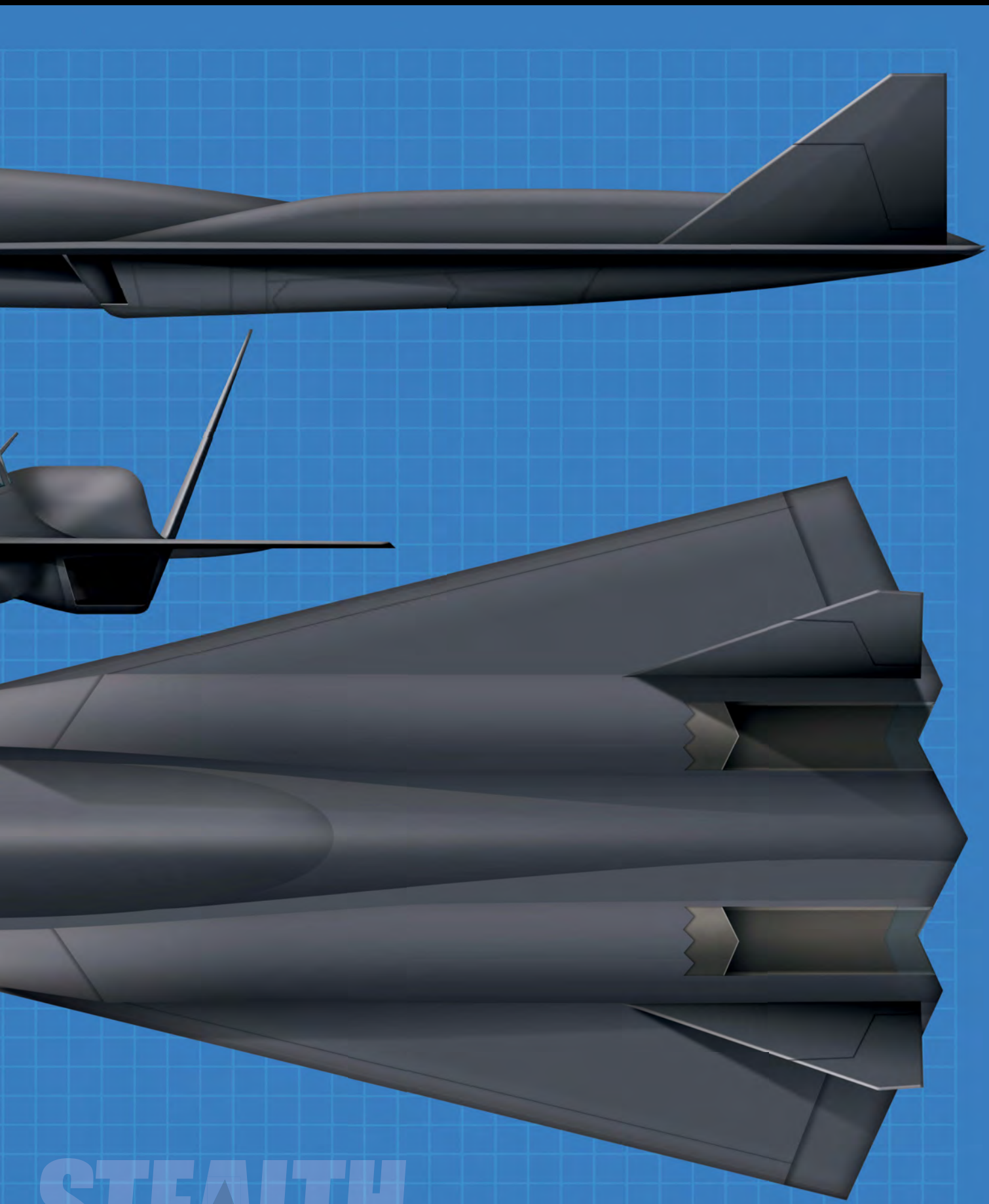
LOCKHEED MARTIN'S ASTRA, AV-6

Cockpit: The tandem cockpit arrangement seats a Reconnaissance Systems Operator beneath an SR-71 style rear canopy, with very little forward vision. The pilot has a more conventional fighter-like canopy, although unusually it hinges forward to allow access. Eyewitness reports from Boscombe Down said that when the aircraft was in the hangar following the crash, the middle section was covered with a tarpaulin, leaving the tail and nose areas exposed. It's presumed that the crew members wore David Clark full pressure suits similar to those worn by personnel in the SR-71 and U-2, as the ASTRA flies at even higher altitudes and speeds.

Tail Section: The outward canted tailfins were new to aircraft designers in the late 1980s and early 1990s, but improvements in military flight control systems (FCS) enabled the outward canted twin tail arrangement to become fitted as standard on the Lockheed Martin YF-22 Lighting II and Northrop/McDonnel Douglas YF-23 Black Widow a few years later.

Nose Area: ASTRA has chines extending from the forward nose section similar to those on the SR-71 Blackbird, it is presumed that the stealthy leading edges of these sections contain passive intelligence or EW gathering systems.

Size: The size of the charcoal-coloured AV-6 is open to debate, but it is believed the aircraft fits into a USAF C-5 Galaxy with some small-scale disassembly. The Boscombe Down example was transported back to Air Force Plant 42 in a C-5 in just one fight.



Andy Hay/www.flyingart.co.uk

work at the base, including the construction of large new hangars – perhaps to accommodate something as exotic as Aurora.

In mid-1999 I was given another rare opportunity to get to the truth when I arranged to interview the US Air Force's outgoing head of procurement programmes, Lieutenant General George Muellner, who as the Principal Deputy, Office of the Assistant Secretary of the Air Force for Acquisition, was leaving the Air Force that very day.

He had agreed to speak on the record about the rationale for black programmes at a time when they were very much in the news – this being the era of the X-Files TV show and a (largely) misplaced perception by the general public that classified Pentagon expenditure was running out of control.

What followed, I believe, although couched in veiled references and a certain amount of double-speak on both our parts, was one of the most honest accounts of what was happening in the black world at the time.

I started by asking Muellner whether he, as the head of everything that had been procured by the Air Force in his name, was satisfied that he knew exactly what was already flying or in development.

"I believe so," he said. "It's one of those questions you never know the answer for sure, but I think the answer is yes."

I then asked what the Air Force was developing in the black, and Muellner said: "Things that push the envelope beyond where we're at: next-generation stealth, certain breakthrough weapons technologies, information warfare, spy satellites – that kind of thing."

We then got onto the subject of Aurora – or, strictly speaking, the Air Force need for a very high-flying, hypersonic reconnaissance vehicle. The Air Force, Muellner said, had no need for a reconnaissance aircraft that could fly around the globe at Mach 7 or Mach 8 when the satellites it already had in place could do the same job.

From this interview, which also included a discussion about a strong need at the time to "mature technology", my conclusion, right or wrong, was that there was a window in time when the US Air Force did need a quick-reaction, very high-speed reconnaissance aircraft to find and identify 'pop-up targets'; in particular, those associated with mobile missile launchers – targets that could not be guaranteed to be located by satellites, because the Soviets and their allies knew exactly when US satellites flew overhead.

Above: ***Northrop Grumman's B-21 Long Range Strike Bomber looks much like the B-2 Spirit, the aircraft it is due to replace, posing the question: has the radical exterior design simply been replaced by high-tech, on-board electronic systems?***

As a result, a vehicle conforming to the Aurora platform was built, I believe, and flew as a kind of 'operational prototype' out of Groom Lake, and quite possibly other isolated locations as well between the mid-1980s – when there was an eye to the SR-71's looming retirement date of 1989 (it was reactivated for a period in the 1990s) and the service entry, from 1992 through the rest of the decade, of a new generation of spy satellites.

These were the KH-12 family, with better area coverage and vastly improved 'real-time' capability over the earlier KH-11 generation.

Following the end of the Cold War and the resultant collapse in spending, Aurora, therefore, would have been too expensive (a) to bring into full service and (b) to continue operating, when satellites could do the same job – albeit with some loss of strategic surprise – at a fraction of the expense.

And the reasons for the continued secrecy? Multifold, I believe. Strange as it may sound, Pentagon officials and politicians with oversight of 1980s black projects had backed themselves into a corner over their categorical denials that a stealth fighter existed in the 1980s.

Double-Talk

They did this by working around the very wording used by the media in their questioning of senior military officials and politicians. No, a stealth "fighter" didn't exist (it was a strike aircraft). An F-19 wasn't in service; it was cleverly, and counter-intuitively, branded as part of the Century Series of combat aircraft superseded by the F-14, F-15, F-16 and F/A-18 and so on.

When it came to Aurora speculation several years later, the press had learned its lesson and gave officials who found themselves on the spot much less room for manoeuvre, forcing them into misleading statements if not downright untruths – something, incidentally, that was permitted then (as it is now) under 'special access programme' rules, where deniable projects need to remain so.

Those denials still carry public weight – the thought being: what else might elected officials be covering up? And so the need projects to keep these black.

What can be proven to have emerged out of this golden era of black programmes are a handful of 'onesie-twosie' projects – Northrop's Tacit Blue, Boeing's Bird of Prey, some UAV/UCAV prototypes and some low-number production vehicles such as the Lockheed Martin RQ-170 Sentinel UAV, for example.

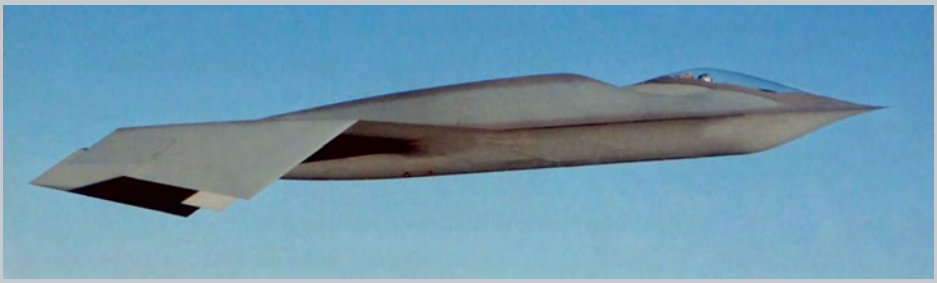
But this output barely scratches the surface in terms of what was actually developed and built and, in my opinion, it is this deeper reservoir of historical capability that will likely remain secret for decades.

Back to Black...

The infrastructure that created these exotic 'semi-mythical' creatures is now so stripped of funding and rationale compared to the Skunk Works of Kelly Johnson and Ben Rich, as well as the 'special projects' departments of Boeing (McDonnell Douglas) and Northrop (Grumman), that it is debatable how much macro-innovation in terms of true 'platforms' – we're talking secret, classified platforms here – it currently accounts for.

The stimulus for the Reagan-era hike in spending was fear – a genuinely held belief in the military and political circles of the day that the Soviet Union had an edge that could only be negated by a bold, disruptive play in America's technological arsenal.

Deployed stealth was one outcome of that fear-driven policy; hypersonics may have been another. What we fear now does not drive investment and innovation in new, highly secret aircraft platforms – even the Northrop Grumman B-21 Long Range Strike Bomber looks like the B-2 – so much as technologies in other fields: detection and imaging, intercept technology, cyber and encryption/decryption. This is the frontier of the black programme today.



Above: ***Boeing unveiled its Bird of Prey during a roll-out ceremony at its St Louis facility on October 18, 2002. Named after the Klingon spaceship that made its debut in the third Star Trek movie, this technology demonstrator pioneered revolutionary advances in low-observable stealth features, tailless aircraft design and rapid construction techniques. Even though the flight testing ended in mid-1999 it took Boeing executives three years to declassify the aircraft.*** *Boeing*

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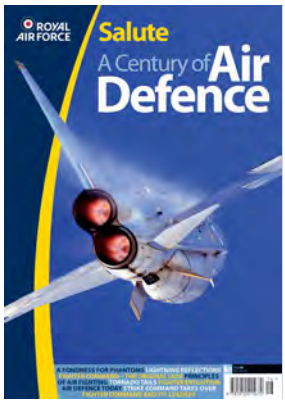

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Stealthy Secrets on the Shoulder

STEALTH BY its very nature is one of the military's most highly classified programmes. Despite the fact that these programmes are a nation's state secret, patches do exist of declassified and yet to be revealed projects.

Why advertise the fact that someone might be involved in a black programme? The best guess is the military's esprit de corps is maintained under what can be difficult circumstances. To wear a patch is telling the world that one is involved in something larger than oneself. Wearing insignia may help preserve whatever secrets a black unit may hold. By displaying a patch, its owner advertises to others that there are certain elements of their job he or she cannot speak about. Their membership of the secret world of aviation society is contingent upon keeping those secrets.

Members of the black world are proud of their clandestine work and wearing a patch may be as far as they can go in explaining what they are doing. **Glenn Sands**

Special Projects Flight Test Squadron

Located at the US Air Force's secret base near Groom Lake, Nevada, the Special Projects Flight Test Squadron is the USAF's only black flight test squadron for classified prototype aircraft and advanced concept technology demonstrators. The aircraft in the lower right is probably a generic symbol representing flight-testing of advanced aircraft. The sword at the bottom of the image refers to the declassified Boeing stealth demonstrator known as Bird of Prey: the handle on the sword approximates the shape of the aircraft (see Bird of Prey).

Minotaur

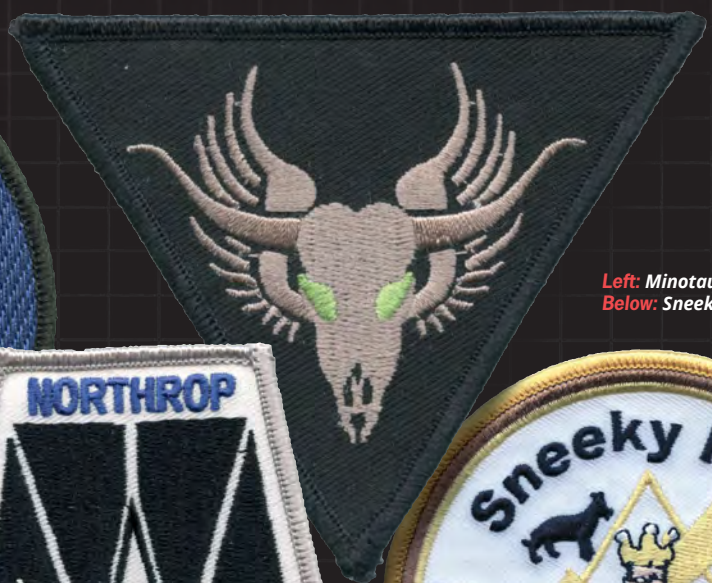
A programme under taken by Lockheed Martin's Advanced Development Programs division, the Skunk Works. Rumours about Minotaur remain obscure, only that the airframe shares a resemblance with another Skunk Works project called Minion, which may have served as a technology demonstrator for the programme.

Northrop Night Stalker II

There is no publicly available information about Northrop's Night Stalker II programme. The II designation suggests there was a Night Stalker I, which remains equally obscure.

Sneeky Pete

An advanced technology demonstrator built by TASK Research of Santa Paula,



Above: ***Special Projects Flight Test Squadron***
Right: ***Northrop Night Stalker II***

Left: ***Minotaur***
Below: ***Sneeky Pete***

Above: ***Bird of Prey***
Above right: ***NKAWTG... Nobody***
Right: ***Vindicator***

Above: ***Janet Aircraft***
Left: ***Ghost Squadron***

California, in 1982, to test early avionics/electronic equipment that could fly a plane remotely, forerunner of today's advanced UAVs, RPVs and UCAVs.

This test-bed was built by Jim Kern, President of TASK, which supplied many composite structures/components for the Dick Rutan-designed Long-EZ, Defiant, and Voyager aircraft during the early to mid-1980s.

The maiden flight of Sneeky Pete took place at Mojave Airport on July 18, 1982 with Rutan at the controls. Sneeky Pete was described as a 'Long-EZ knock off', larger than a standard Long-EZ, with more rounded fuselage sides and a large, bulbous, two-piece canopy.

The aircraft had a retractable nose gear, which was powered by an electric motor. The wing root to fuselage joint was blended/contoured and flowed seamlessly into the cockpit. Sneeky Pete was outfitted with various special avionics depending on the specific mission requirement.

It's believed the flight-testing for Sneeky Pete was held at the remote test site in Nevada starting in late 1982 and is still ongoing.

The aircraft has been put into storage at various times, but has never been officially retired. Later the aircraft was equipped with a jet engine, and it may have contributed to today's advanced UAVs which include: the Northrop/Grumman Global Hawk, General Atomics Predator, Boeing X-45, Northrop/Grumman X-47 Pegasus. No official photographs of Sneeky Pete have ever been released.

Bird of Prey

A highly classified technology demonstrator that first flew at Groom Lake in 1996. Built within a secretive division of Boeing, known as the Phantom Works, the aircraft was flown by company test pilots Rudy Haug and Joe Felock. Although the shape of the aircraft was secret in 1996, the Bird of Prey patch contained a clue. When Boeing declassified the aircraft's existence in 2002, it became obvious that the handle of the sword was essentially the same shape as the aircraft.

NKAWTG...Nobody

This patch comes from a yet unidentified air refuelling squadron tasked with supporting black aircraft projects. The object in the spook's hand is a refuelling boom from either a KC-135 or KC-10. The letters NKAWTG at the bottom of the image refers to the unofficial motto of Air Force's tanker fleet: No One Kicks Ass Without Tanker Gas.

Janet Aircraft

Boeing 737s known as the Janet Fleet are white and wear a red stripe; they use the callsign 'Janet' when in civilian airspace. The fleet is operated by the Special Project Division of EG&G and the company's logo provides the backdrop for the smiling aircraft in the centre. The Janet aircraft shuttles military and civilian workers to and from their jobs at the secret military bases such as the Tonopah Test Range and Groom Lake, home to many stealth projects past and present.

Vindicator

Built by Lockheed Martin's Skunk Works, the Vindicator system was a highly classified project, rumoured to be more secret that the F-117A from the 1980s. This patch includes the Lockheed Advanced Development Projects' skunk mascot wearing a helmet and scarf. The patch depicts a laser anemometer optical air data system, which takes the place of a conventional pitot-static probes on stealth or high-speed aircraft where protrusions are undesirable. The device is a velocity indicator, otherwise known as a v-indicator.

Ghost Squadron

The text on this patch translates as: A Secret Squadron, From Deep in the Night, Don't Ask Any Questions. An obscure unit called the Ghost Squadron, which operated out of the USAF base near Groom Lake, wore the patch. The unit was a helicopter support squadron tasked with providing security and SAR for squadrons flying classified stealth projects.

Although various stealth aircraft have emerged from the 'black world' into the public domain, flown in combat and in some cases even been retired, the technology remains as vital today as it did back in the early 1970s. The cover of darkness may hide most combat aircraft from plain sight, but hiding from an enemy's radar is a completely different matter. *Richard Cooper*

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